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PROCEEDINGS

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OF THE

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AMERICAN RAILWAY ENGINEERING ASSOCIATION
59 East Van Buren Street
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Stress Measurements on Various Designs of Solid Manganese Crossing Frogs

Installed in the Crossing of the Baltimore & Ohio Chicago Terminal and the Atchison, Topeka & Santa Fe at McCook, Ill.

Preliminary Report Committee 5—Track

The report presented here covers an investigation carried out on behalf of the Committee on Track as a part of its assignment No. 4—Plans for switches, frogs, crossings, spring and slip switches. The subcommittee assigned to this particular subject is as follows: E. W. Caruthers (chairman, subcommittee), L. L. Adams, J. C. Aker, C. A. Anderson, E. W. Backes, T. H. Beebe, F. J. Bishop, C. W. Breed, B. E. Crumpler, H. Q. Day, L. W. Deslauriers, J. A. Ellis, J. W. Fulmer, R. A. Gravelle, N. M. Hench, A. B. Hillman, A. F. Huber, W. G. Hulbert, C. T. Jackson, L. I. Martin, F. H. Masters, R. E. Miller, J. B. Myers, G. A. Peabody, O. C. Rehfuss, C. J. Rist, L. H. Roden, G. J. Slibeck, C. R. Strattman, H. N. West, R. P. Winton, J. G. Wishart, and M. J. Zeeman.

This investigation was a cooperative project of the Association of American Railroads, the Manganese Track Society, and the Baltimore & Ohio Chicago Terminal Railroad. The Manganese Track Society furnished the various designs of castings used in the test, and the railroad installed the castings with its own forces. The test measurements were conducted and the report was prepared by M. F. Smucker, assistant electrical engineer of the Engineering Division research staff, AAR, under the general direction of G. M. Magee, research engineer, and Randon Ferguson, electrical engineer. All of the direct expenses involved in making the test, with the exception of the cost of the castings, were assumed by the AAR.

The purpose of the investigation was to study the cause of cracks which have occurred with some frequency in the flangeways of solid manganese crossing frogs. The location at McCook, where the double-track line of the B.&O.C.T. crosses the double-track line of the Atchison, Topeka & Santa Fe Railway at an angle of 75 deg. 48 min. (See Figs. 1 and 6) was selected for the test because of the heavy traffic density to which the crossing is subjected and the fact that considerable trouble with flangeway cracks had been experienced. Frog location 6 on Crossing 2 (Fig. 1) was selected for the test frog. In December 1943, a preliminary series of tests was conducted at this same location, using a casting corresponding to the AREA design and having a grillwork supporting the casting floor. (See Fig. 38). This same design of casting had been tried previously in this location and failed from very bad flangeway cracks in a comparatively short time. Tests conducted on this casting indicated that high flangeway stresses were due primarily to the lack of sufficient girder strength. High tension stresses were found to exist in the flangeway when the casting was bowed upward between wheels, and high compressive stresses when the wheels were directly over the flangeway.

Purpose of Preliminary Tests

One of the primary purposes of the preliminary tests was to determine the practicability of actually measuring stresses in a crossing frog under regular trains. The measurement of these stresses, particularly in flangeways, has only recently become practical by the development of the Baldwin Southwark SR–4 type wire resistance gage,

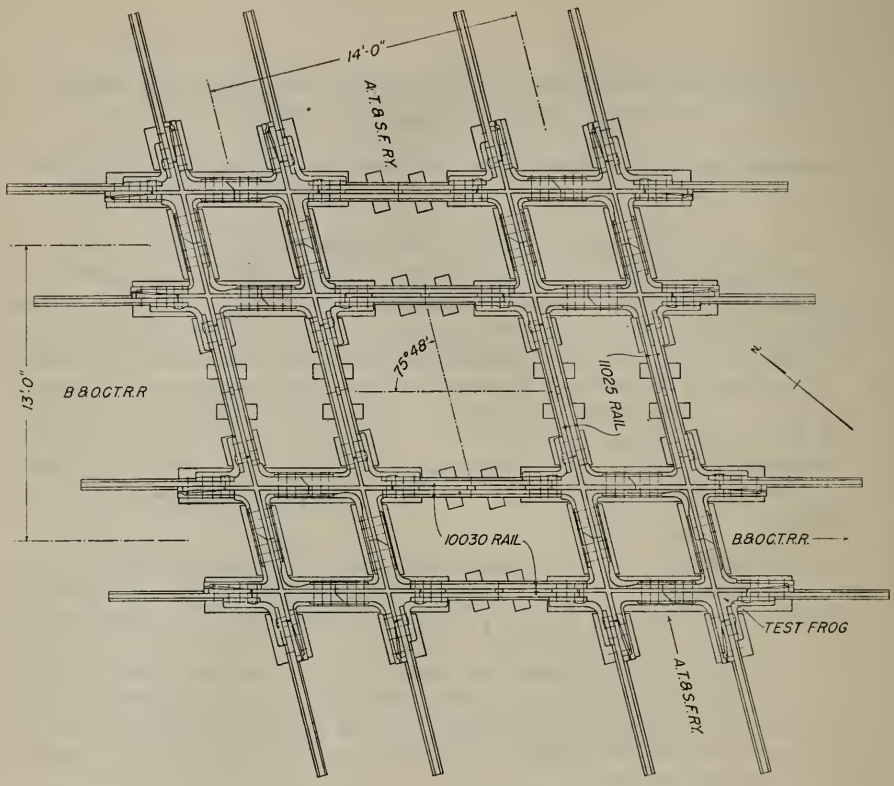


Fig. 1.—Plan of the Crossing at McCook, Ill.

and the research staff has only recently acquired equipment suitable for recording the stresses indicated by this type of gage. (Although the word "stress" is used throughout this report, it should be understood that actually the strain is measured and the stress is computed therefrom on the basis of the modulus of elasticity relation between stress and strain for manganese steel). Complete records were not secured in these preliminary tests because it was found that sufficient waterproofing protection had not been provided for the gages, but the test did demonstrate that measurements were entirely practical and could be successfully made.

Accordingly, a comprehensive test program was planned for 1944. The various frog manufacturing companies were asked to submit designs of castings for test. These designs were studied and four were selected for test purposes which represented substantial differences in design and were thought to offer the best opportunity for developing constructive information. Each casting was designed for the same location; that is, frog location 6 on Crossing 2 as shown in Fig. 1. The four different casting designs are shown in Figs. 2 to 5, inclusive. The castings differed only in the design of the base and means of supporting the flangeway floor. The base construction is also shown in the photographs (Figs. 8 to 11, inclusive).

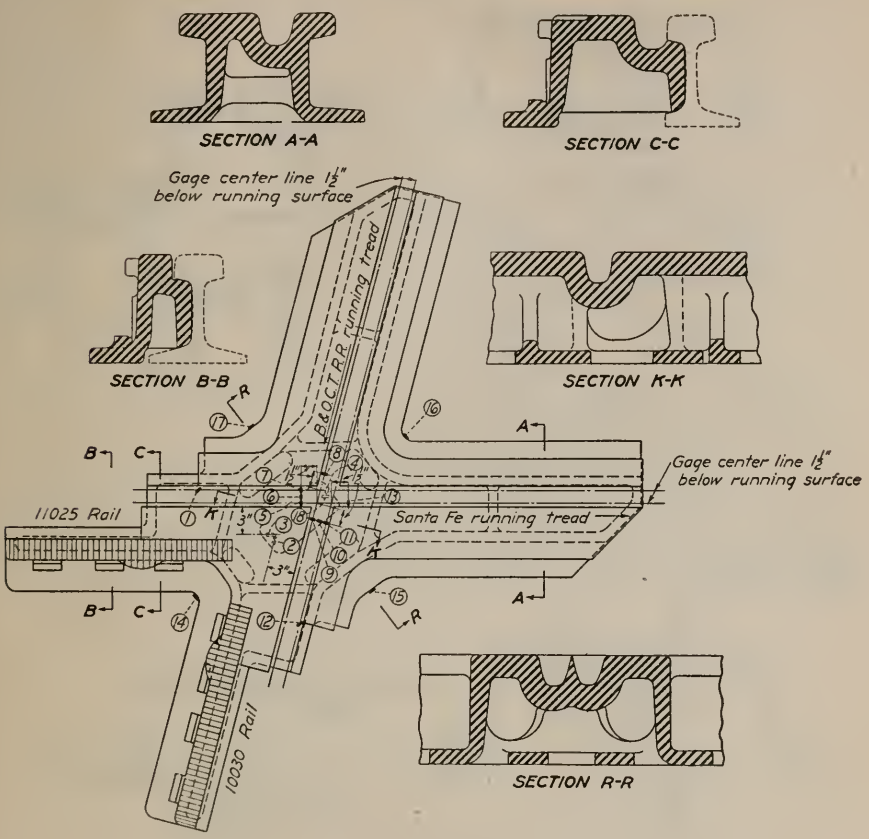


Fig. 2.—The Taylor–Wharton Design.

Before the tests were made additional ballast was added and the crossing was tamped up and put in good condition by the B.&O. track forces. The castings were tested, one at a time; when the test of one casting was completed it was removed and replaced with a different design. The fourth casting tested—the Morden–Ramapo design —was also tested in a second series of tests, using a different tie arrangement and with the base plates removed between the casting and the ties, as shown in Fig. 14.

Where the Gages Were Placed

Before the test casting was placed in the crossing the wire resistance gages were cemented at the desired locations and the connecting wires were all placed in position (Fig. 12). The location of the various gages and their designating number is shown on the plans of the four castings (Figs. 2 to 5). Gages 1 and 12 were placed in a diagonal position where the guard rail joined the casting, at which location cracks had occasionally been found to occur in service. Gages 5, 7, 8, 9, 11 and 13 were placed to measure the fillet stresses in the flangeways in a direction transverse to the length of flangeway at a height 1½ in. below the running surface. Gages 6 and 10 were placed in the bottom of the flangeways to measure the stress in the transverse direction. Gages 14,

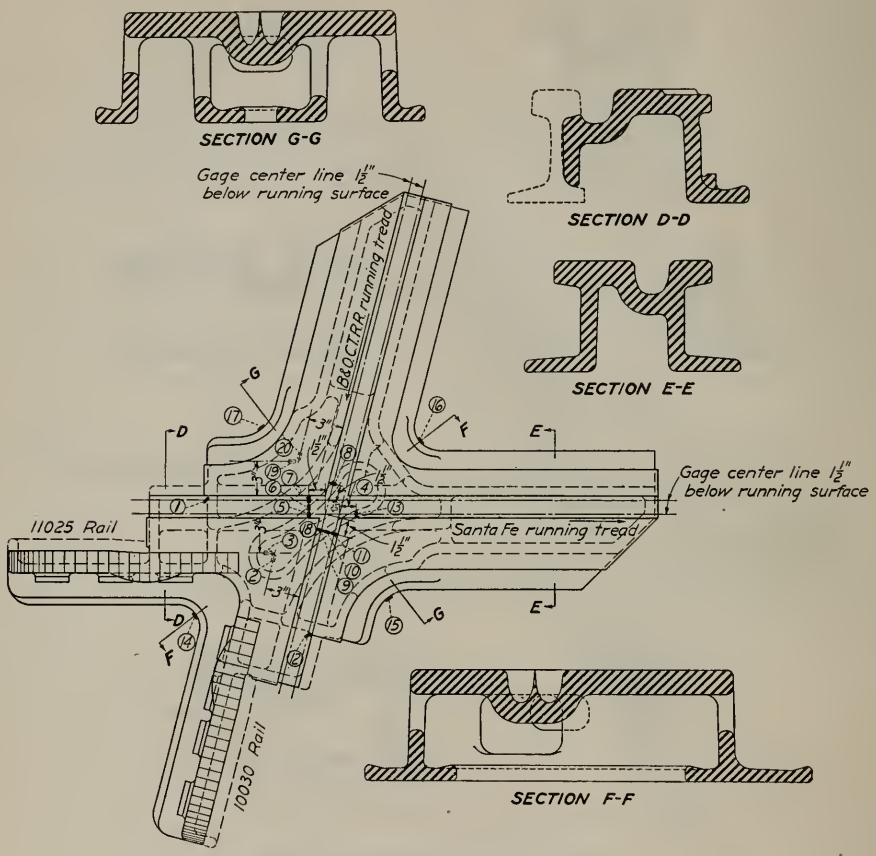


Fig. 3.—The Carnegie–Illinois Design.

15, 16 and 17 were placed to measure the fillet stresses at each corner intersection of the base flange of the frog. The remaining gages were placed underneath the flangeway floor at accessible locations, as shown in Figs. 2 to 5. The gages had gage lengths of ¼ in.

With the recording equipment available (Fig. 13) it was only possible to secure measurements simultaneously at six gages. Accordingly, it was necessary to make the tests on each position in three different schedules. Six gages were connected in each schedule and measurements secured under a number of trains on both B.&O. and the Santa Fe tracks. During the tests of the four castings, measurements were secured under 490 trains. Because of the more frequent train movements over the B.&O. track a considerably larger number of B.&O. runs were obtained than Santa Fe runs. The test runs were started on August 14 and completed September 18. Fig. 15 is a typical stress record. On this record have been added certain explanatory data identifying the run, speed, locomotive, and gage numbers. Base or zero stress lines have also been drawn. Wheel arrangement has been superimposed on the wheel marker record in the lower part of the figure. A wheel marker was placed on the B.&O. track so that each wheel gave an indication at 100 in. before reaching the flangeway, and on the Santa Fe track at 60 in.

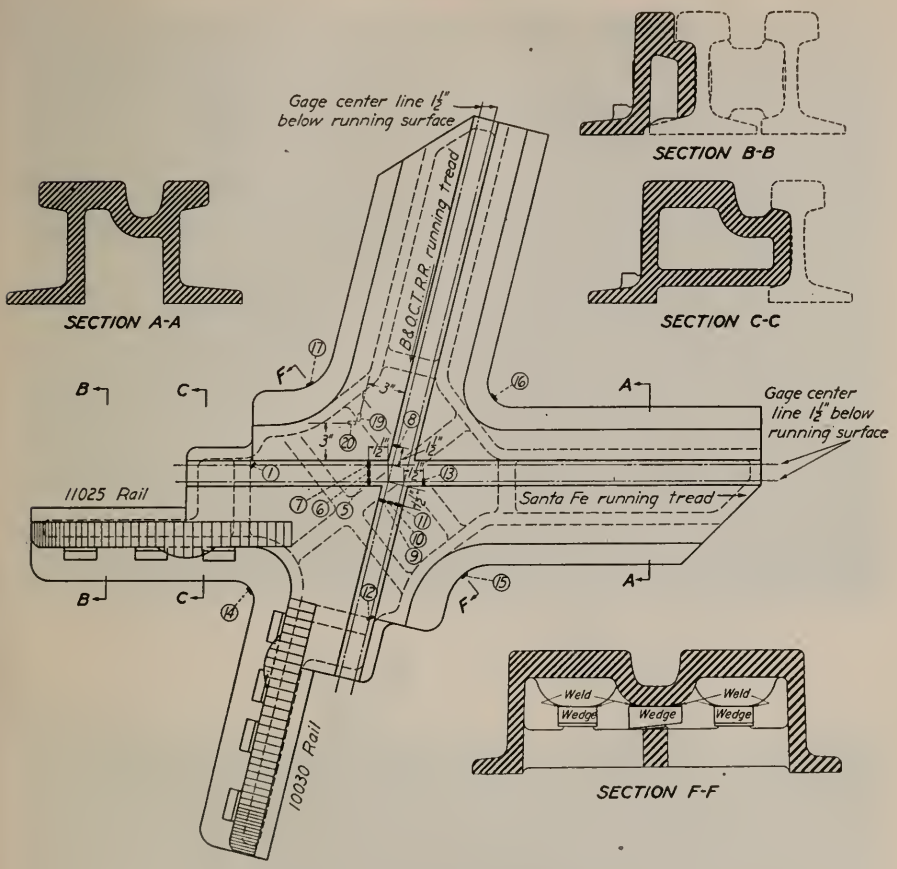


Fig. 4.—The Bethlehem Design.

before reaching the flangeway (See Fig. 14). This permitted correlating the stresses measured at any gage location with the wheel positions.

Discussion of Test Measurements

In analyzing the records, the maximum tension and compression stresses recorded under the locomotive and tender were determined. Records were also taken under several cars following the locomotive, and the maximum tension and compression stresses recorded under the cars were also determined. Maximum stresses under 10,000 lb. per sq. in. tension or compression were not used in working up the data because stresses this small were not considered important.

In order to present these maximum stresses as concisely as possible, Figs. 16 to 35 have been prepared. Each figure shows the maximum measured stress noted during one run at one gage location for all four of the castings tested for both B.&O. and Santa Fe traffic, and separately between locomotive and cars. On each figure is shown, for convenience, a sketch of the casting with the gage location indicated.

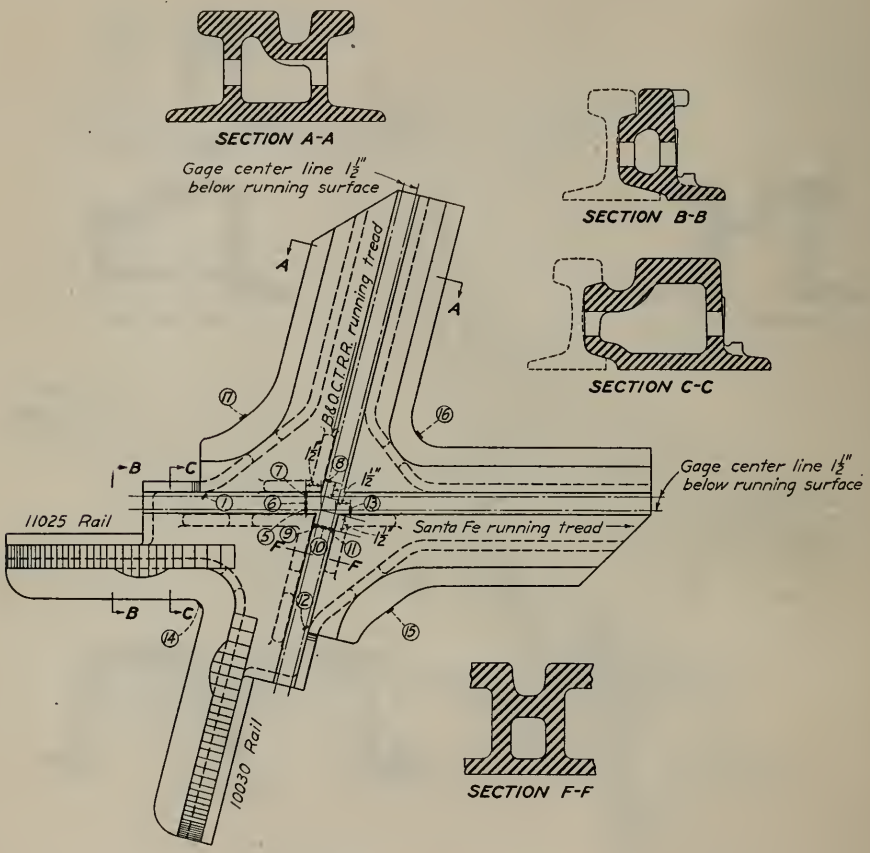


Fig. 5.—The Morden–Ramapo Design.

A study of these figures shows stresses at only a few gage locations of sufficient magnitude to indicate the probable development of fatigue cracks. The discussion, therefore, will be confined primarily to these gage locations.

Gage No. 11 is located in the B.&O. flangeway at the point where it cuts the Santa Fe running tread, the gage being on the fillet that is on the receiving side of the flange for Santa Fe traffic. Rather high stresses in both compression and tension were recorded on this gage. From a study of the individual records it was found that a peak tension stress occurred at this location when the approaching wheel first contacted the casting, about 17 in. from the flangeway. A high compressive stress of very short duration was produced when the wheel crossed the flangeway and struck the receiving tread. As the wheel left the flangeway the tension gradually increased, a rather abrupt peak tension stress being again produced when the next wheel first contacted the casting. The records indicated that the casting was being bowed upward between the wheels under Santa Fe traffic.

Records of the tests of the Taylor–Wharton and Carnegie–Illinois designs did not show as high stresses at gage No. 11 as for the Bethlehem and Morden–Ramapo designs.

(text continued on page 35)

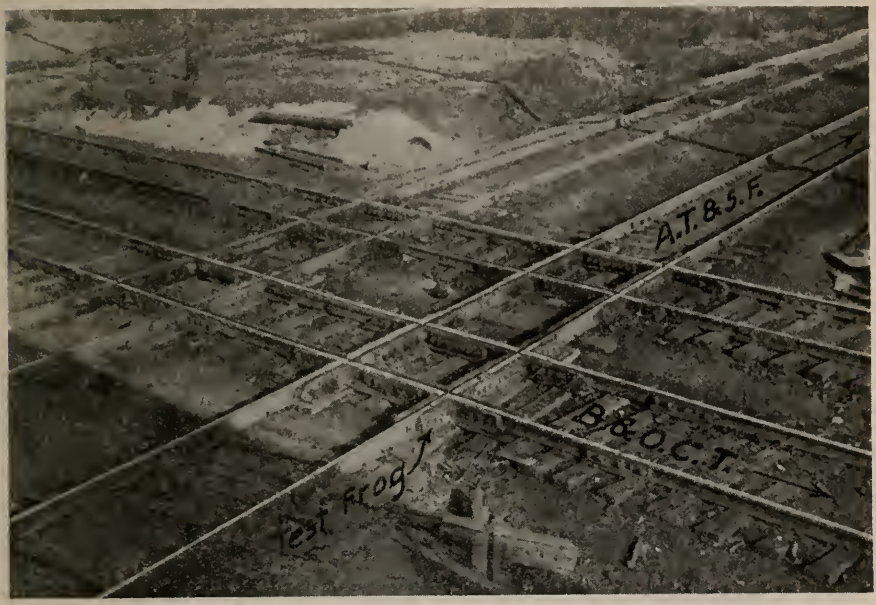


Fig. 6.—The Double Track Crossing of the B.&O.C.T.R.R. and the A.T.&S.F.Ry. at McCook, Ill.

Fig. 7.—Test Casting in Right Foreground, Showing Lead Wires to Gages and Arrangement of Tie Support.

Fig. 8.—Base of the Taylor–Wharton Casting.

Fig. 9.—Base of the Carnegie–Illinois Casting.

Fig. 10.—Base of the Bethlehem Casting.

Fig. 11.—Base of the Morden–Ramapo Casting.

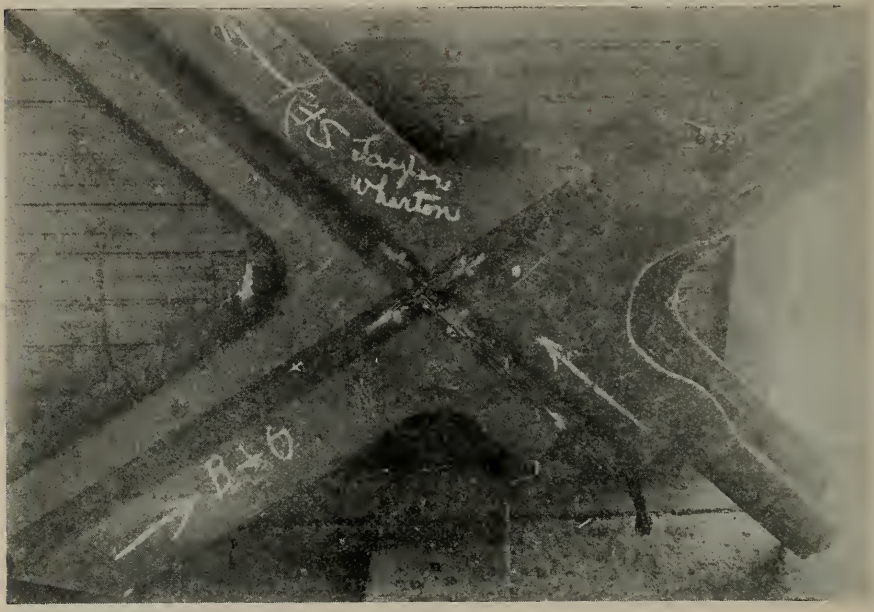


Fig. 12.—Wire Resistance Gages and Wiring Applied in Flangeways and Base Intersections of Taylor–Wharton Casting.

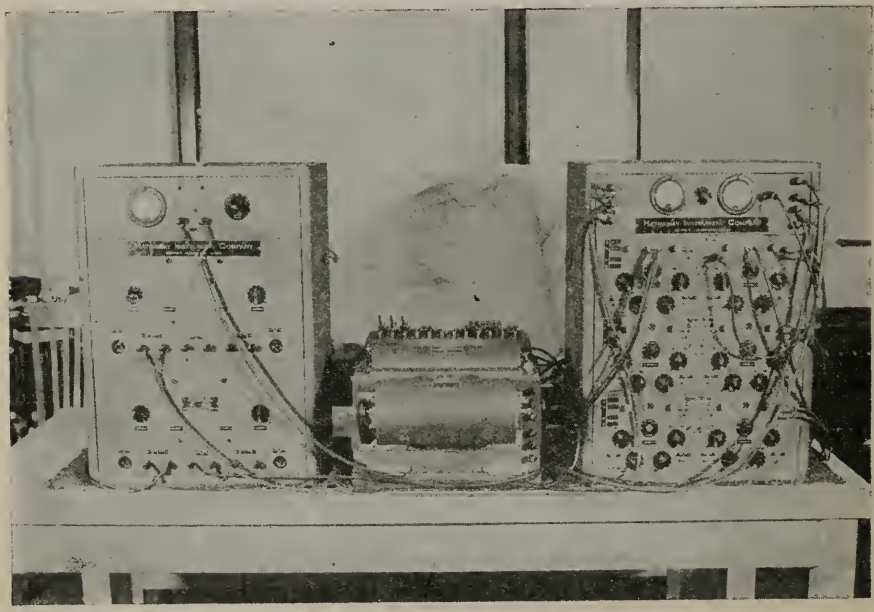


Fig. 13.—Oscillograph and Amplifier Units Used to Record Stresses in the Tests.

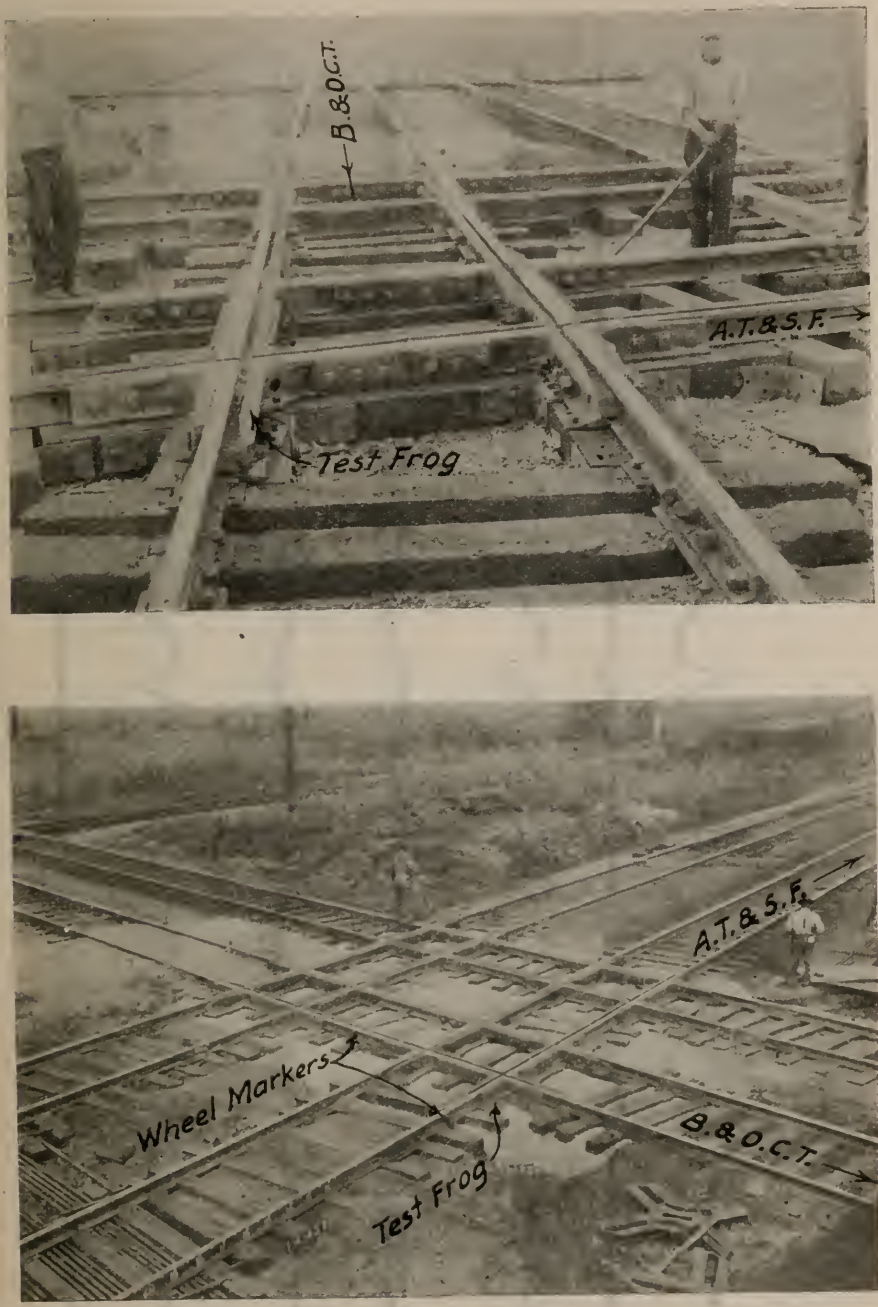


Fig. 14.—Revised Tie Arrangement Used for Second Series of Tests with Morden–Ramapo Casting. Top View Shows the Ties and Corner Brackets During Installation.

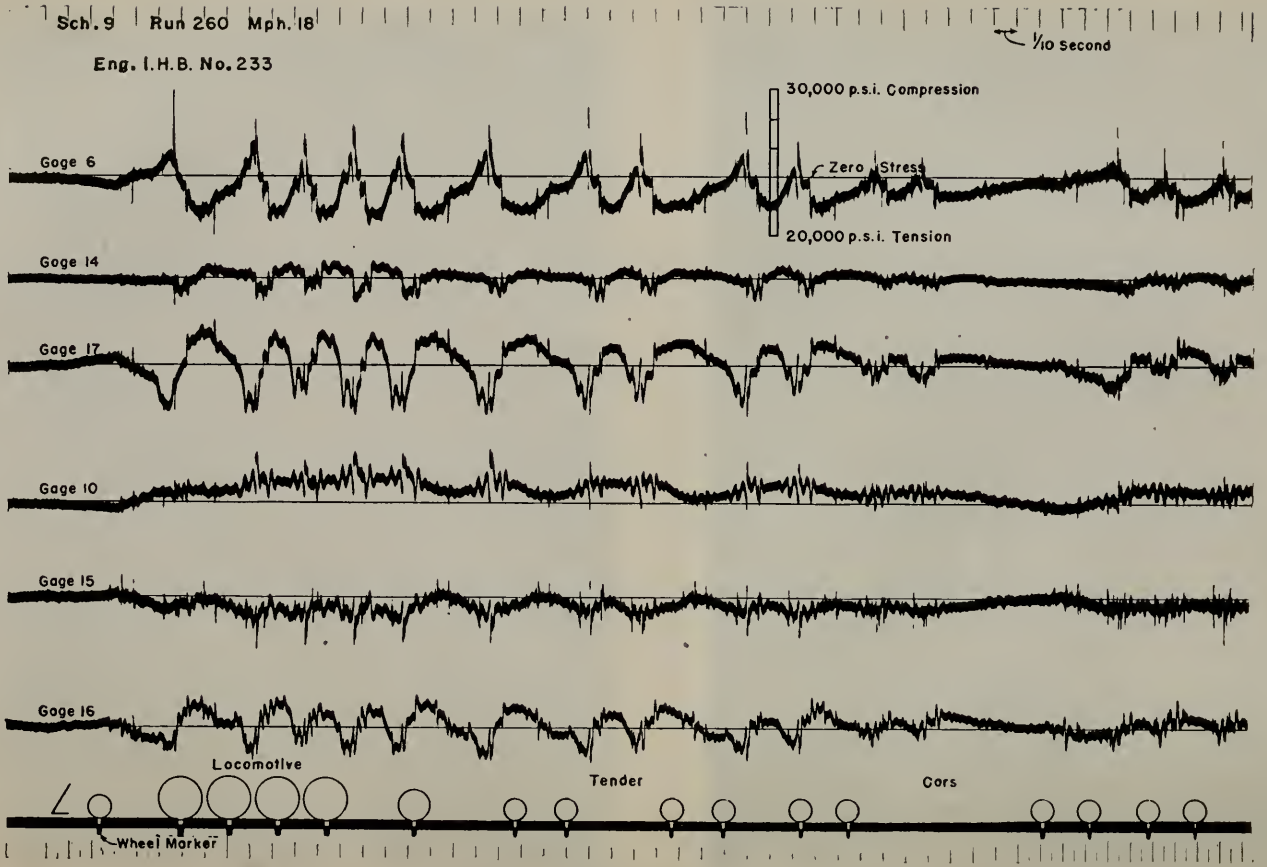


Fig. 15.—Typical Stress Record.

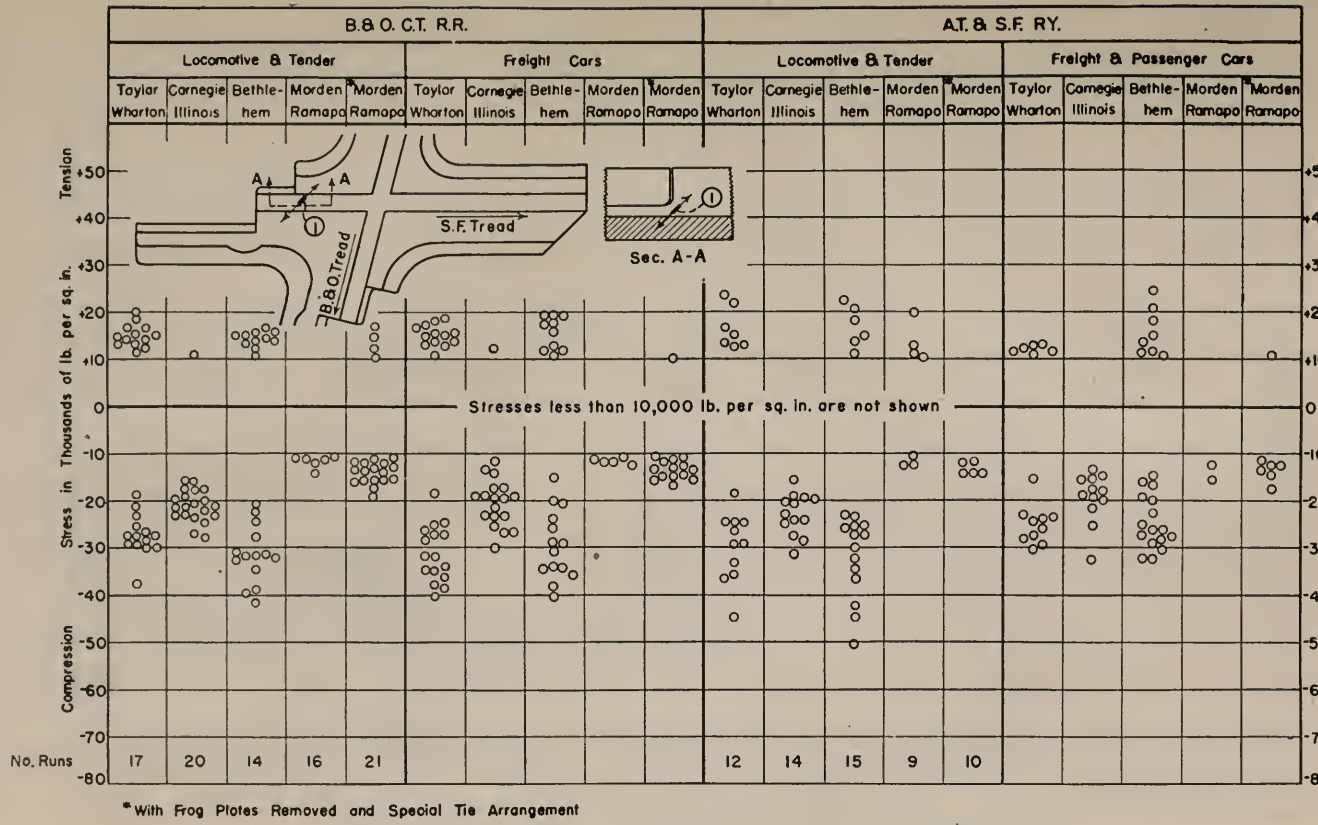


Fig. 16.—Maximum Measured Stresses in the Four Frogs. Gage No. 1.

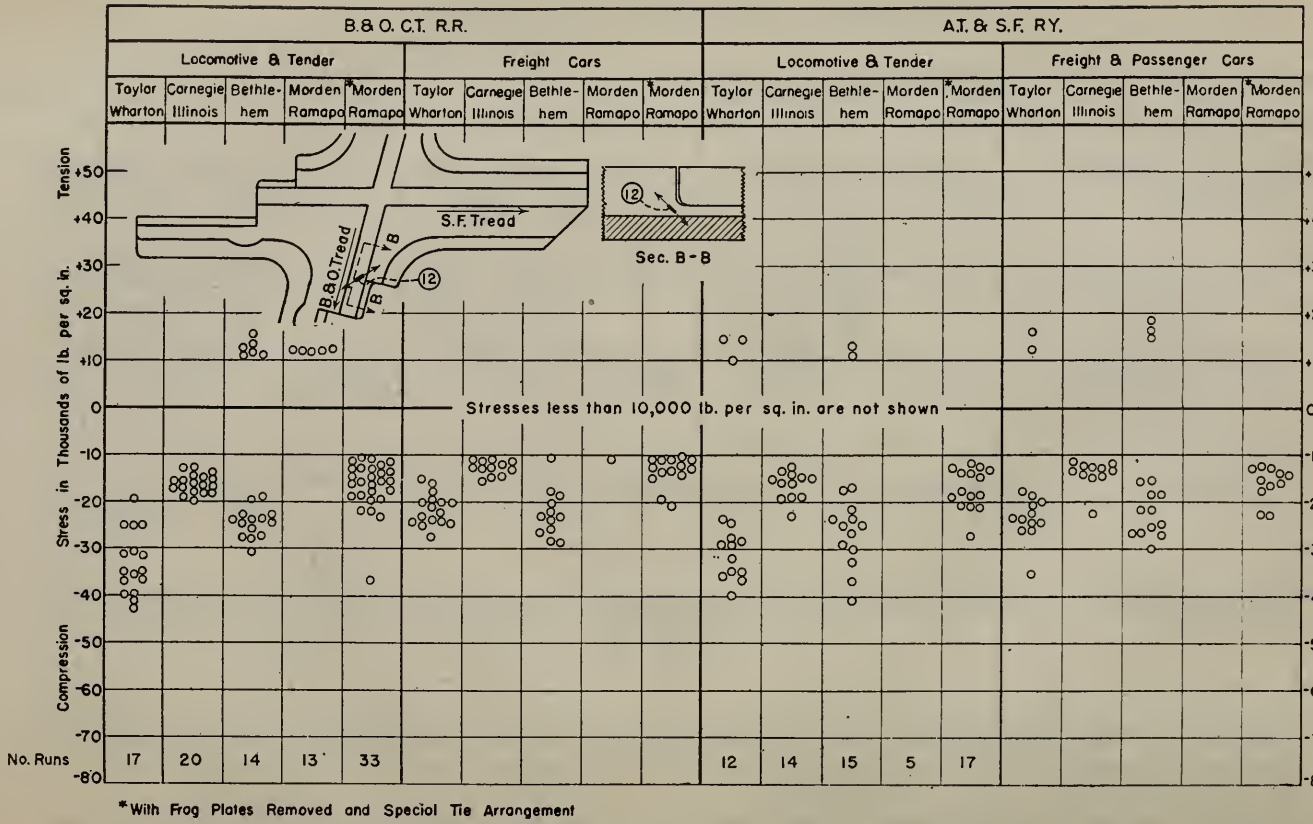


Fig. 17.—Maximum Measured Stresses in the Four Frogs. Gage No. 12.

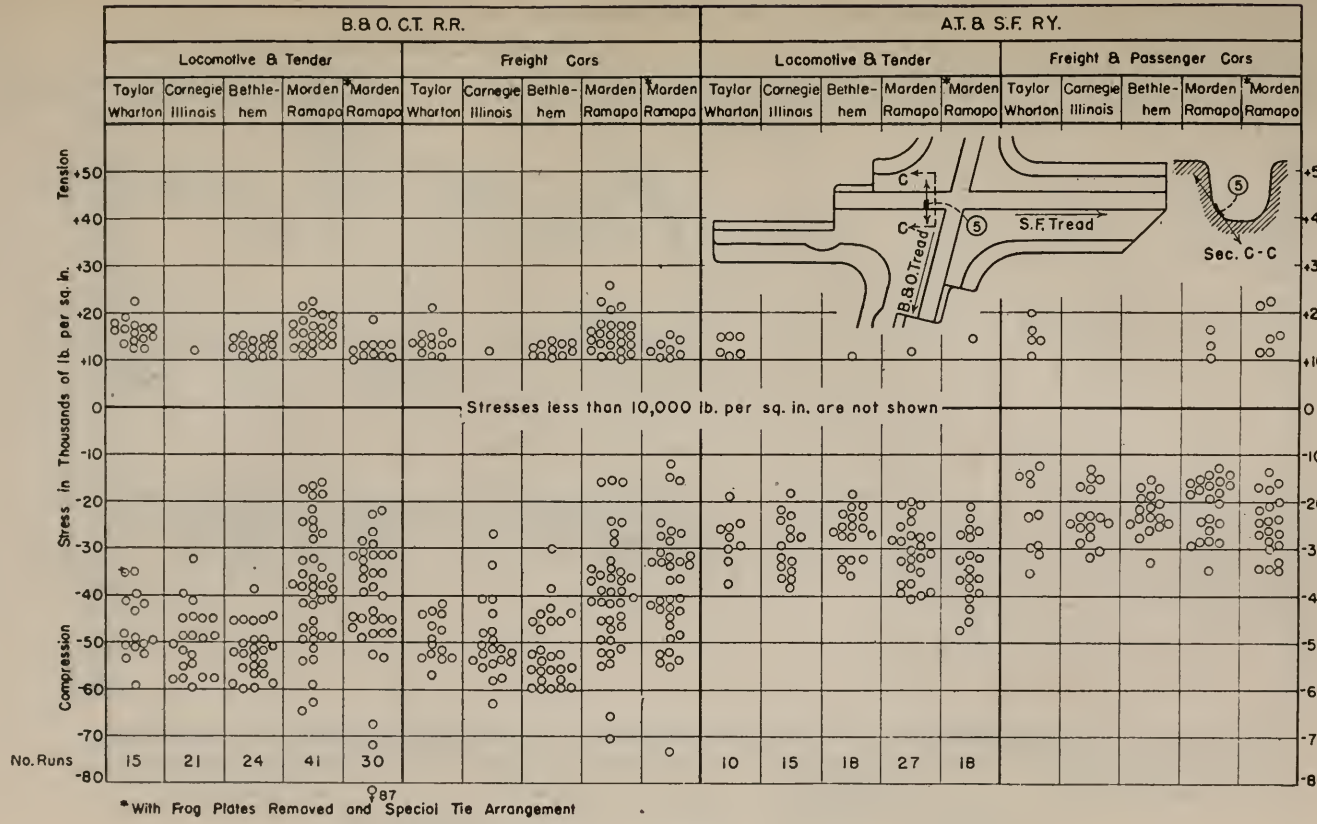


Fig. 18.—Maximum Measured Stresses in the Four Frogs. Gage No. 5.

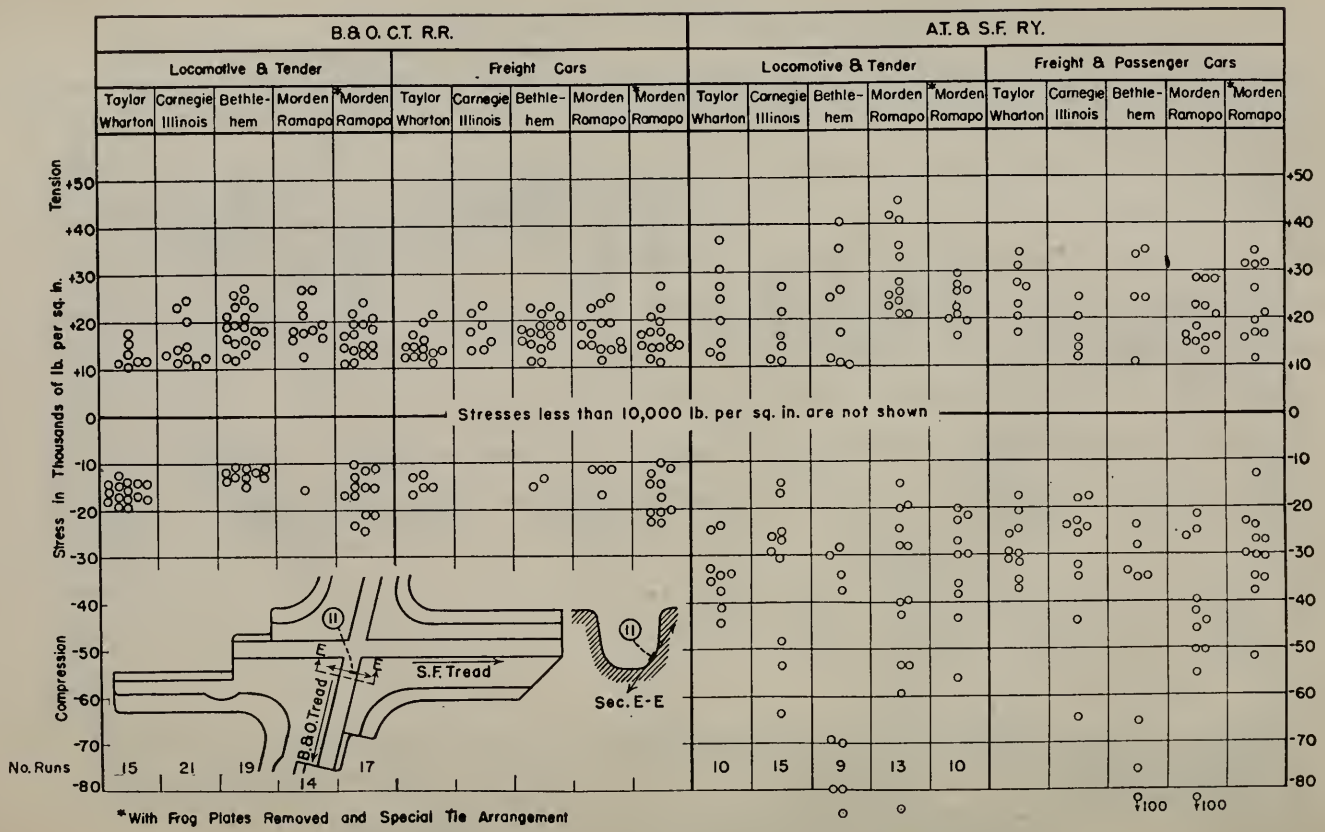


Fig. 19.—Maximum Measured Stresses in the Four Frogs. Gage No. 11.

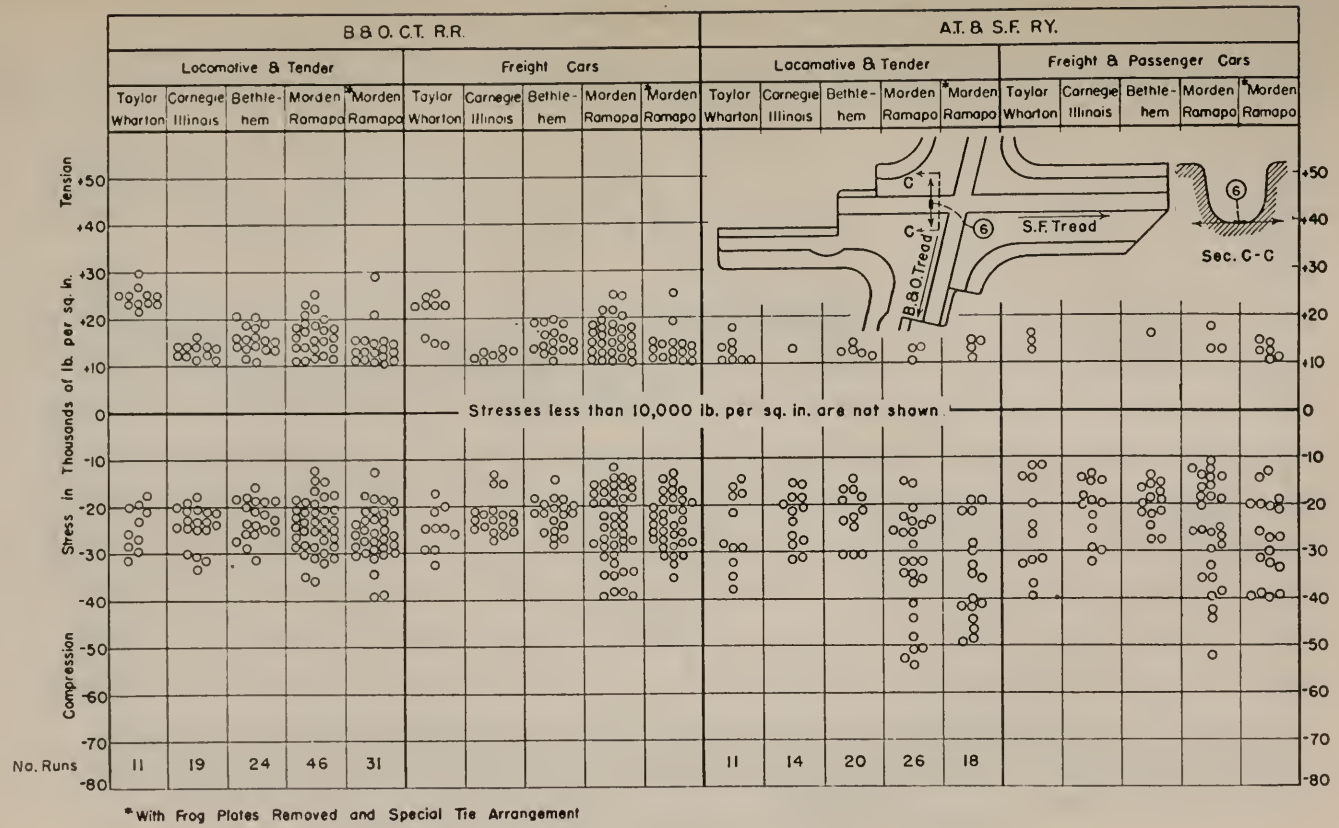


Fig. 20.—Maximum Measured Stresses in the Four Frogs. Gage No. 6.

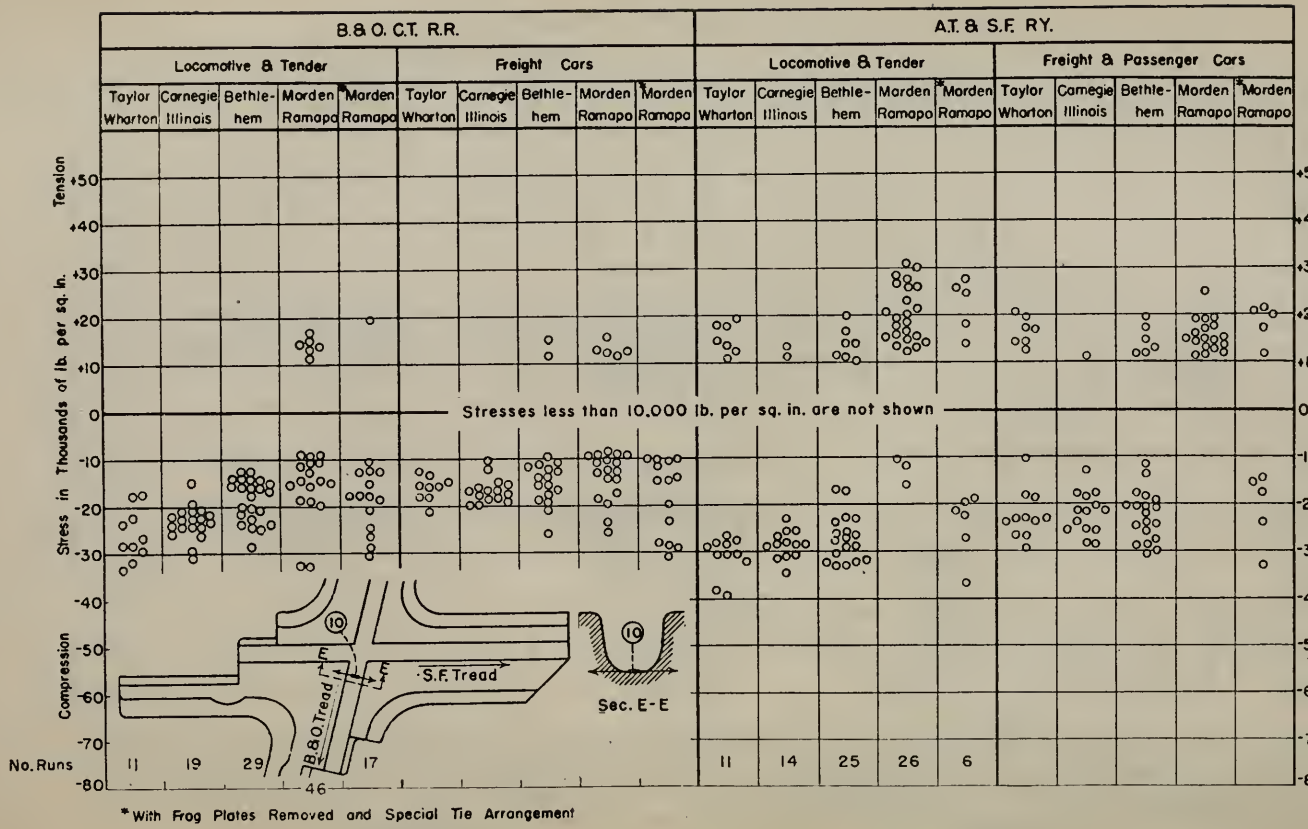
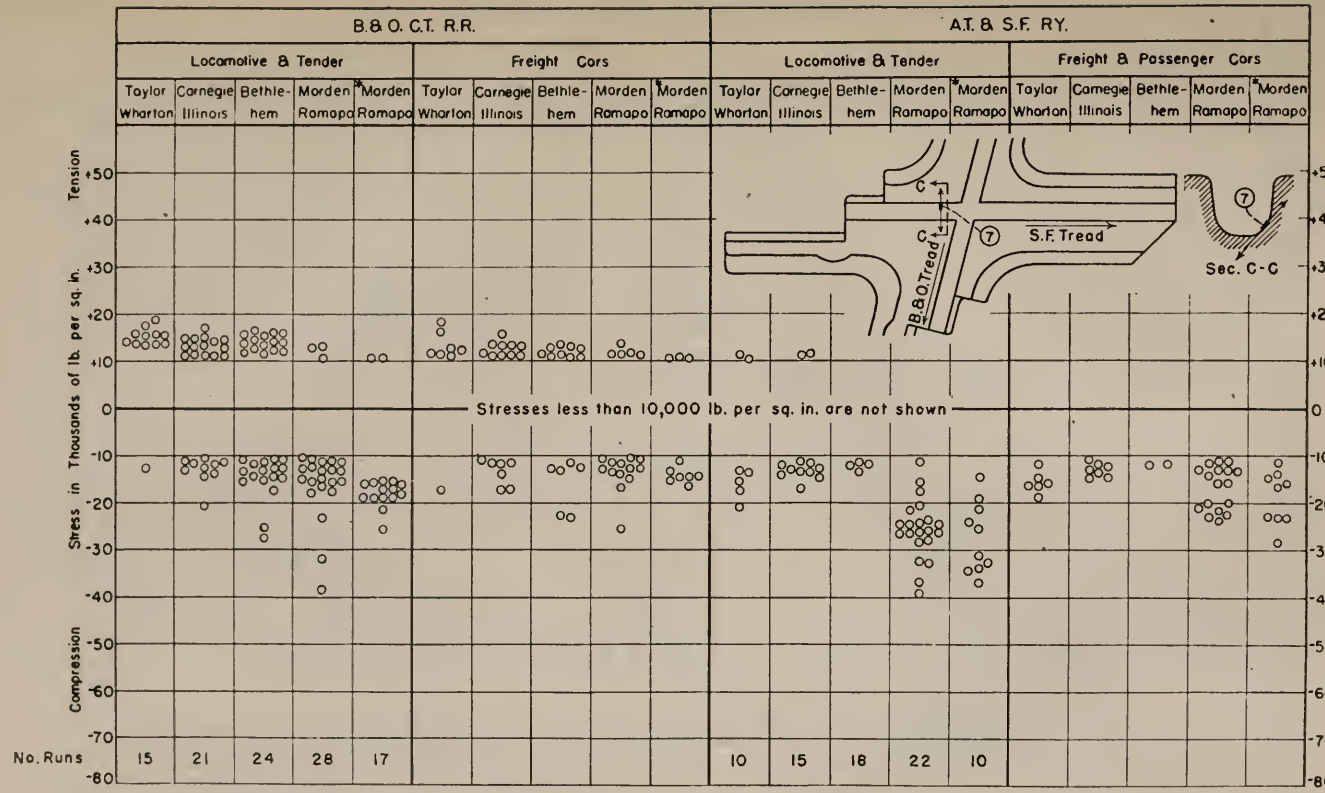


Fig. 21.—Maximum Measured Stresses in the Four Frogs. Gage No. 10.



*With Frog Plates Removed and Special Tie Arrangement

Fig. 22.—Maximum Measured Stresses in the Four Frogs. Gage No. 7.

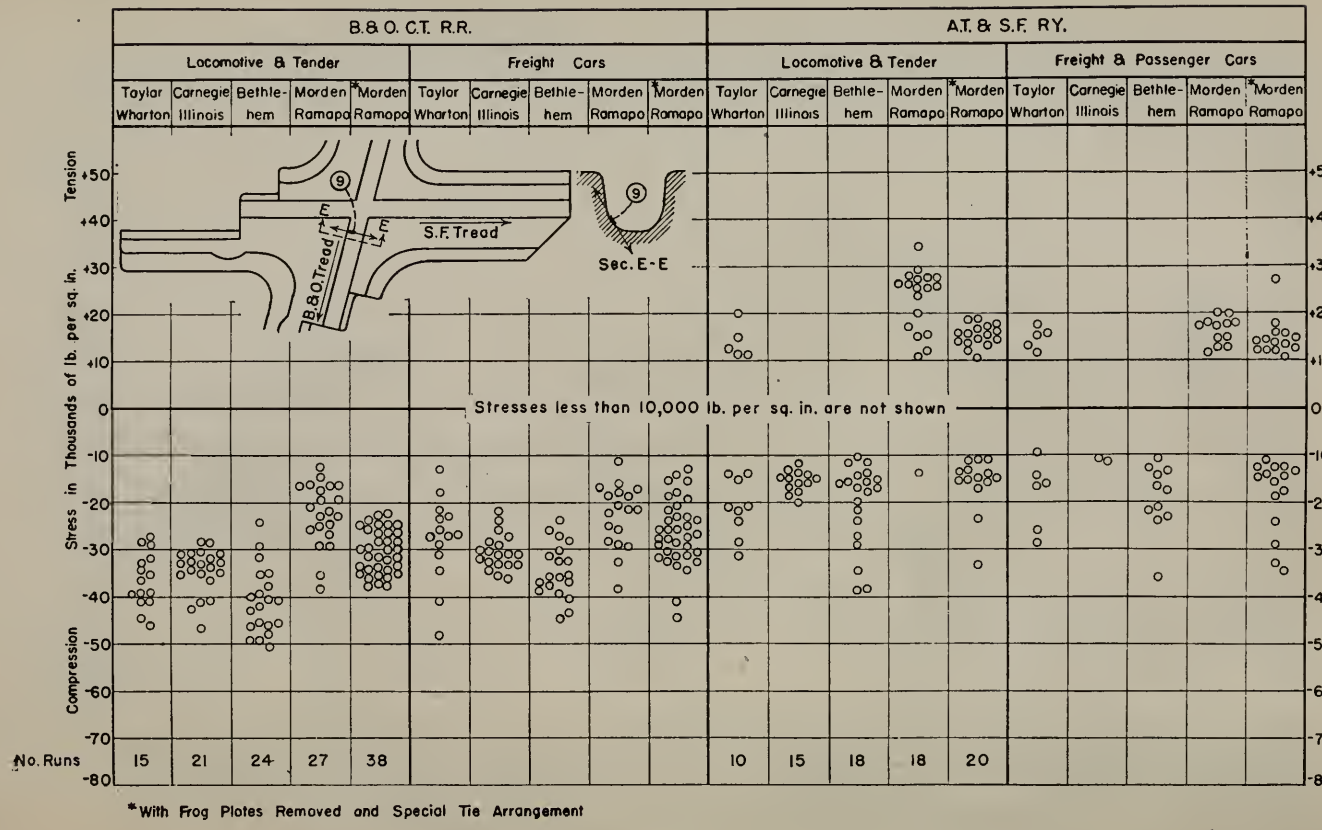


Fig. 23.—Maximum Measured Stresses in the Four Frogs. Gage No. 9.

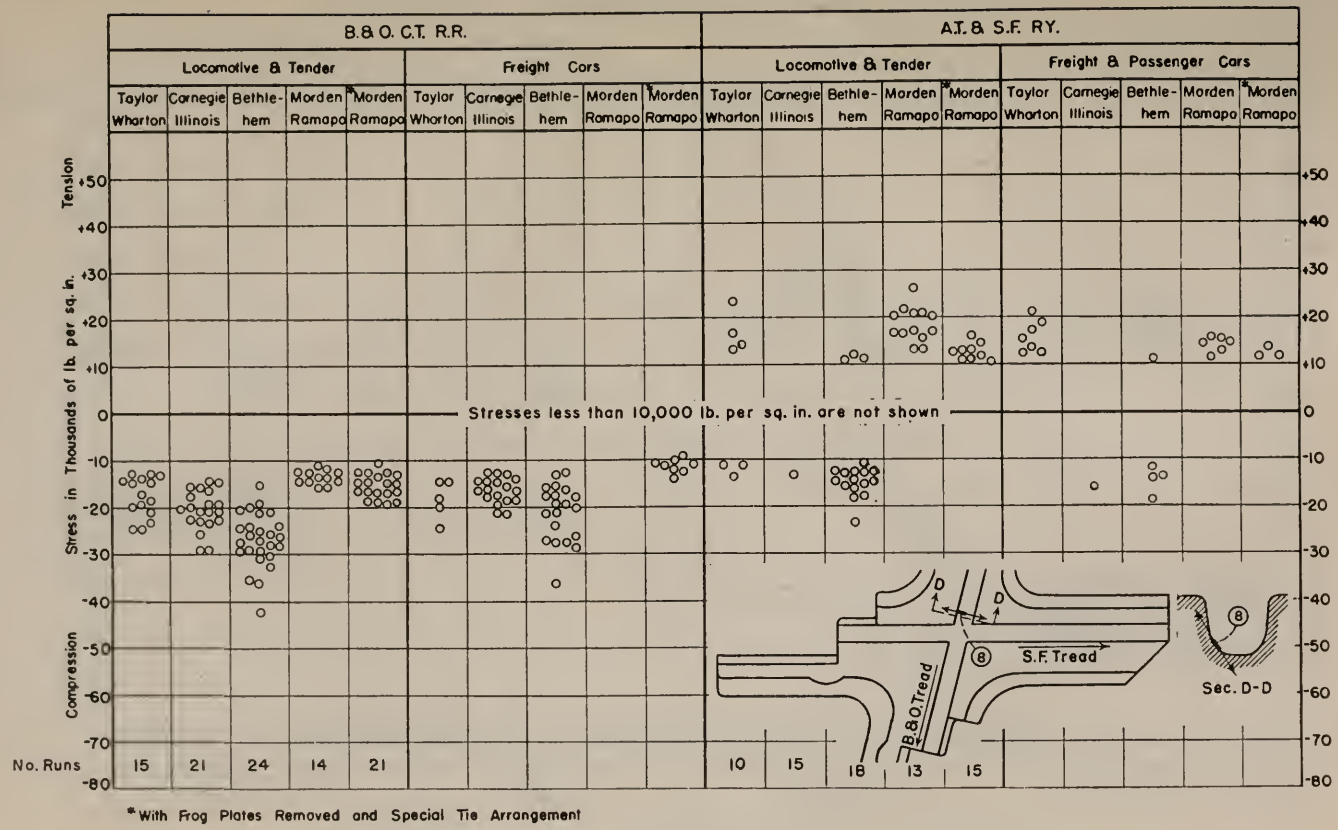


Fig. 24.—Maximum Measured Stresses in the Four Frogs. Gage No. 8.

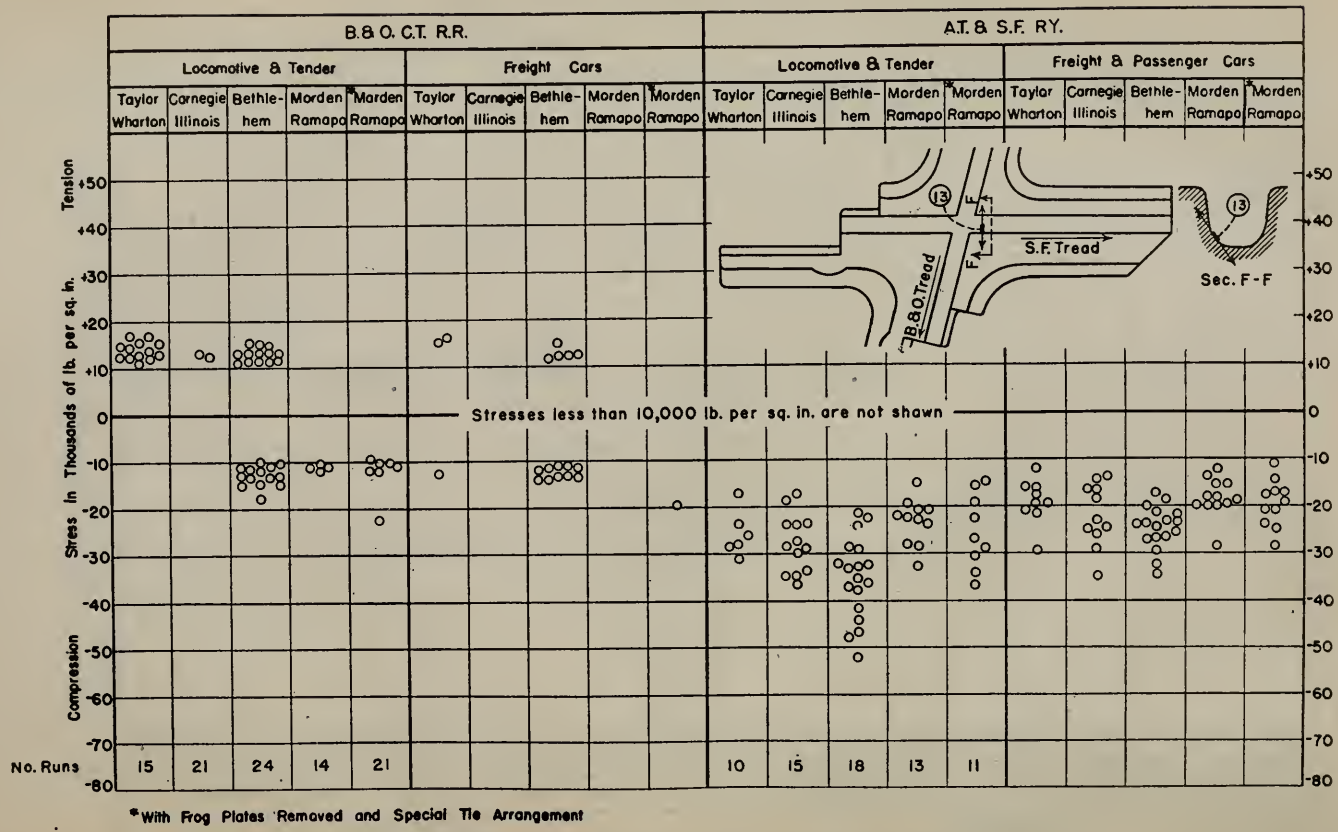


Fig. 25.—Maximum Measured Stresses in the Four Frogs. Gage No. 13.

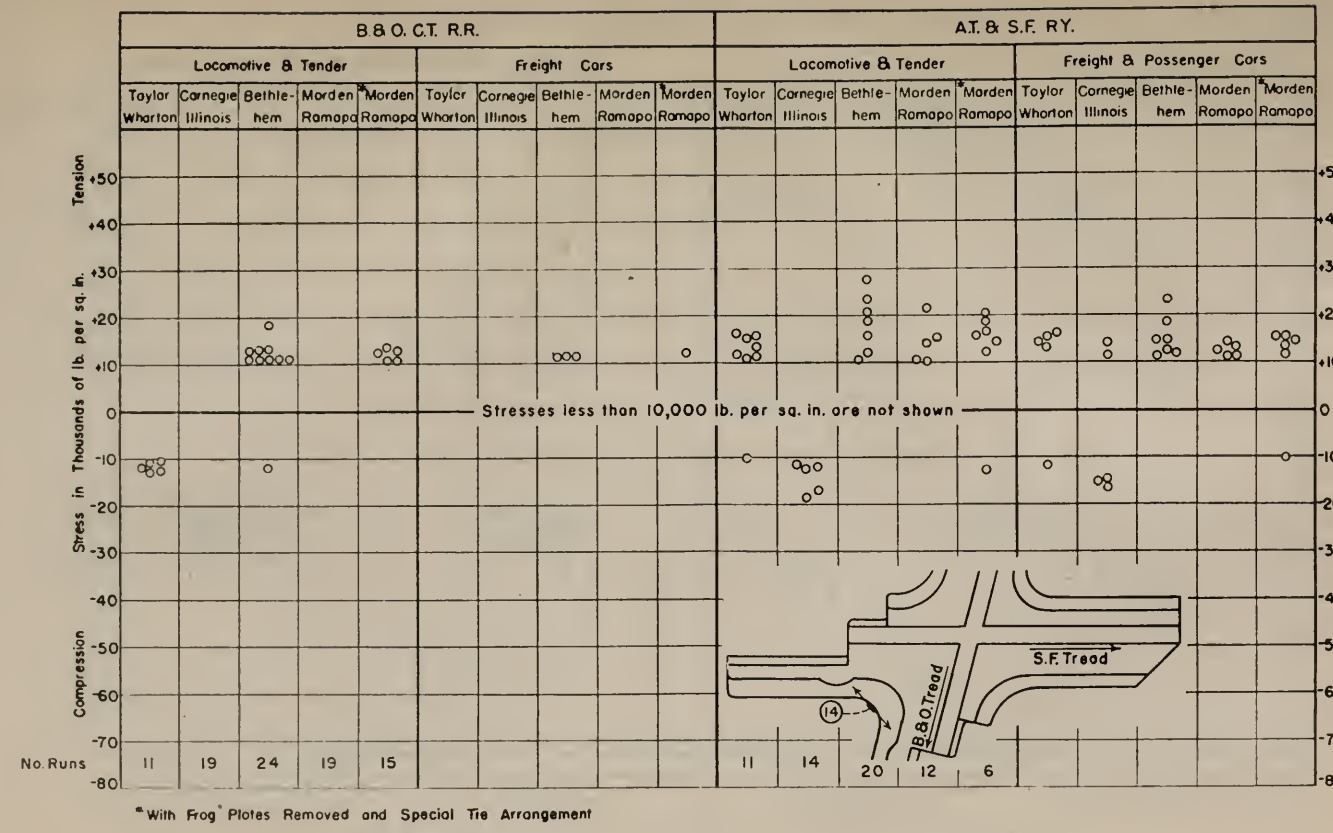


Fig. 26.—Maximum Measured Stresses in the Four Frogs. Gage No. 14.

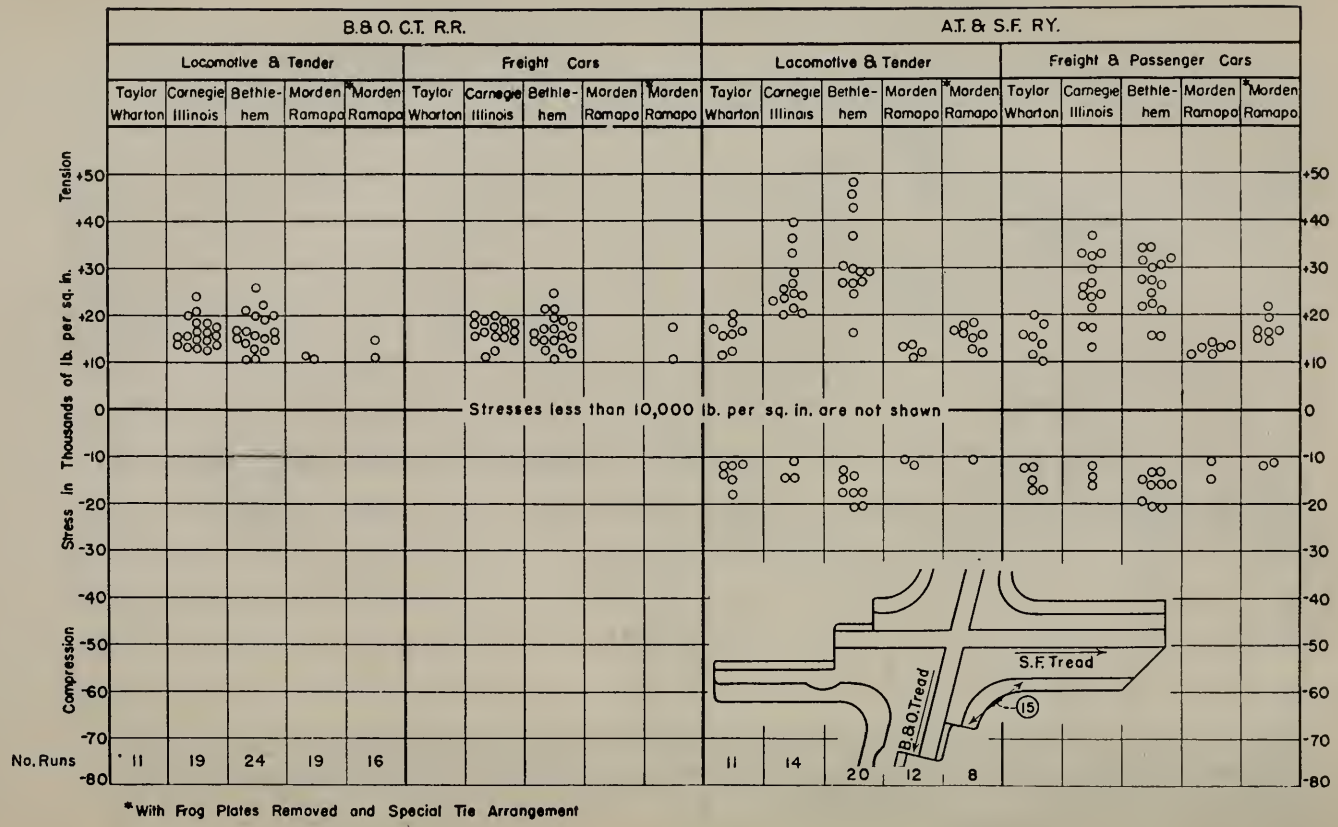


Fig. 27.—Maximum Measured Stresses in the Four Frogs. Gage No. 15.

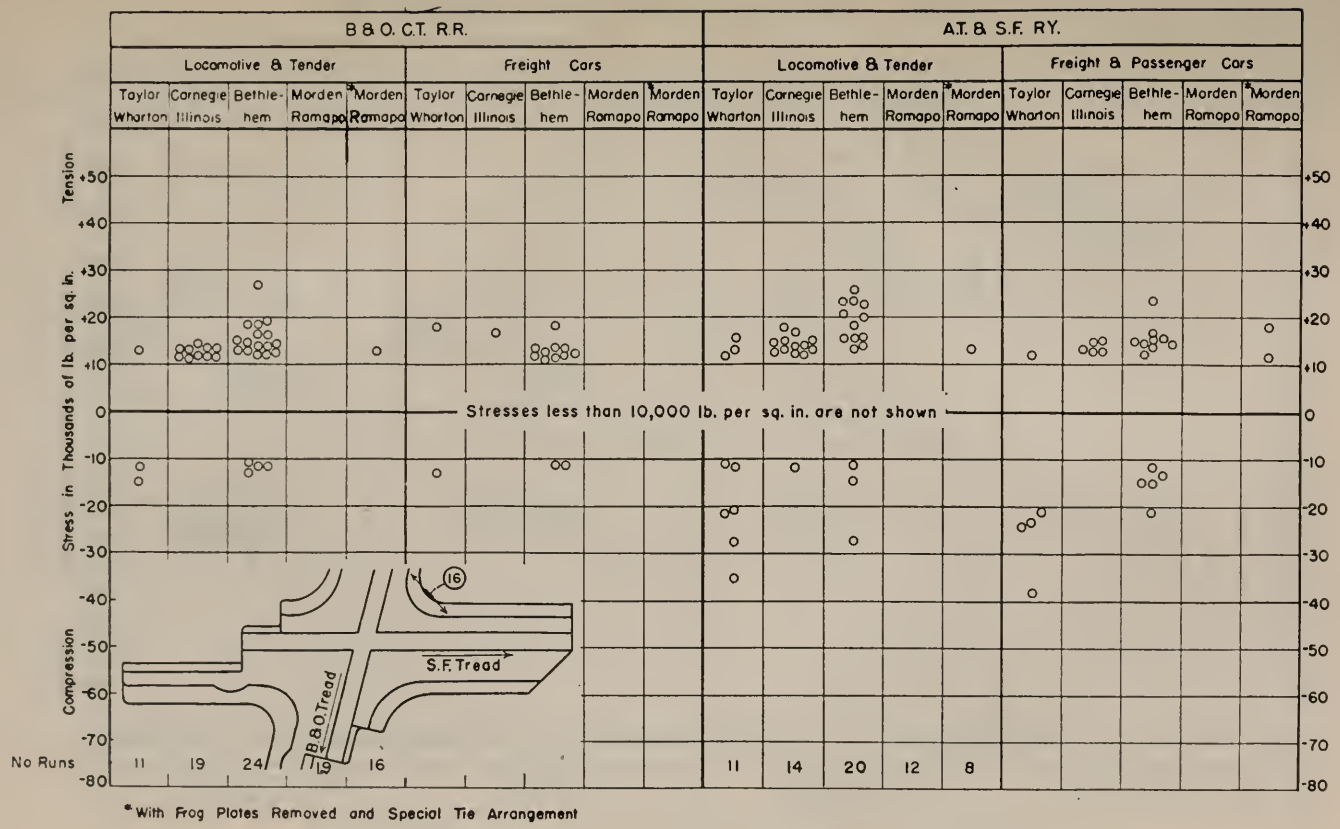


Fig. 28.—Maximum Measured Stresses in the Four Frogs. Gage No. 16.

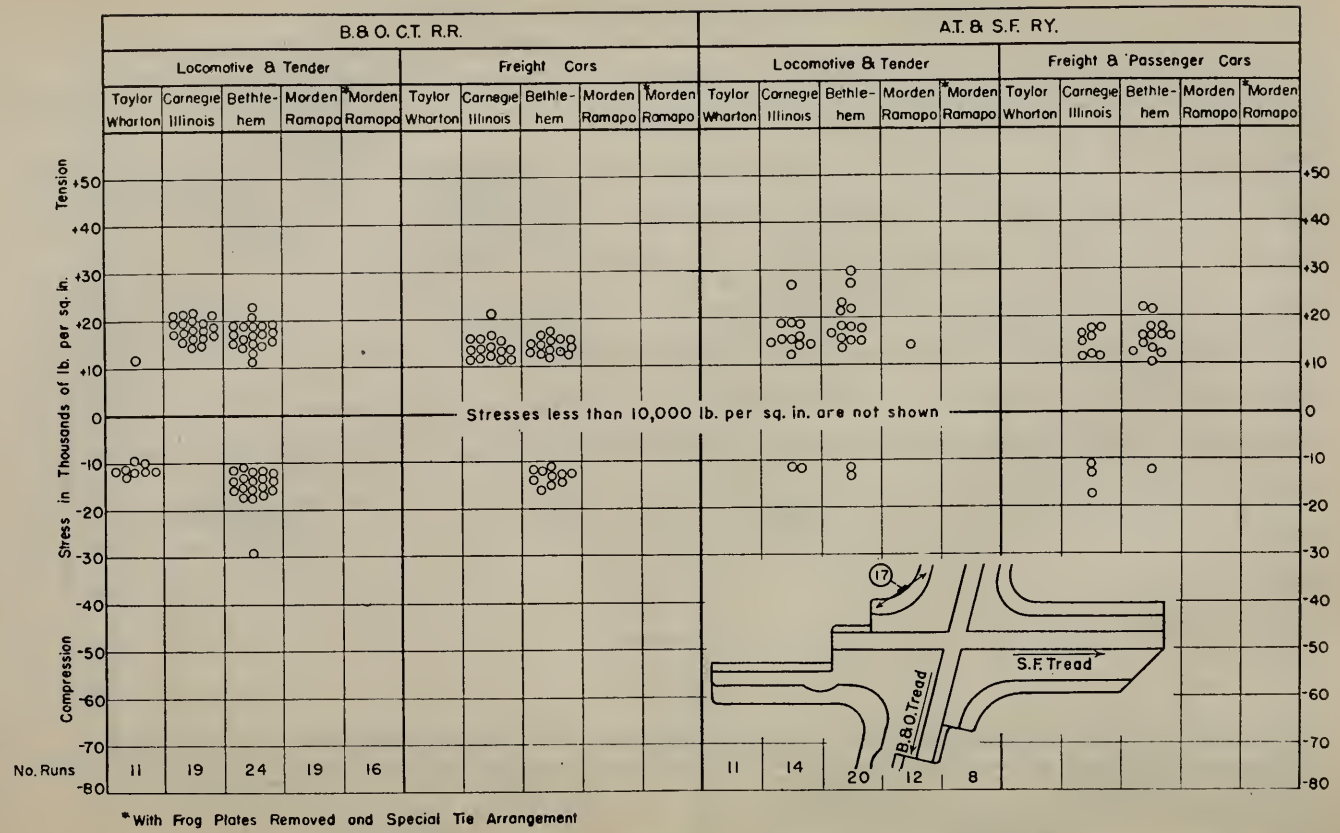


Fig. 29.—Maximum Measured Stresses in the Four Frogs. Gage No. 17.

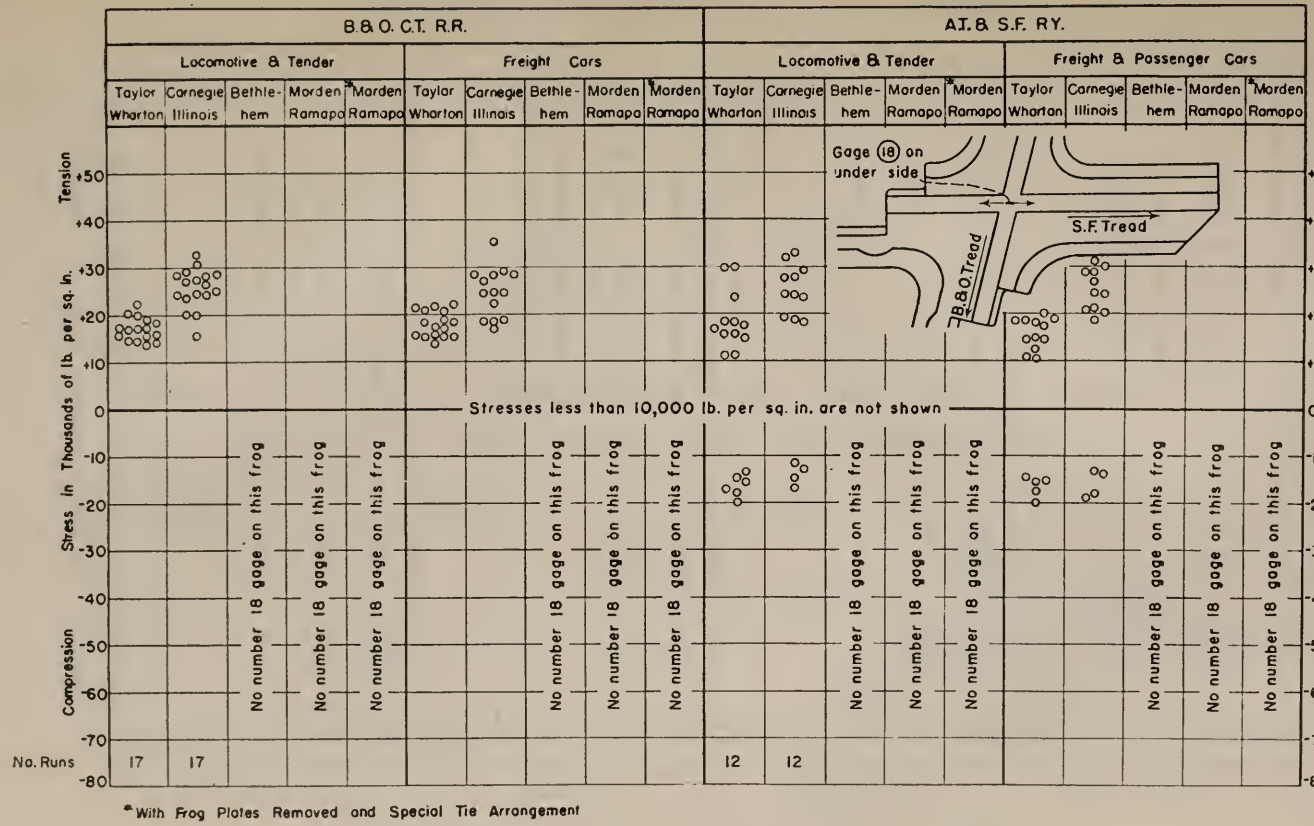


Fig. 30.—Maximum Measured Stresses in the Four Frogs. Gage No. 18.

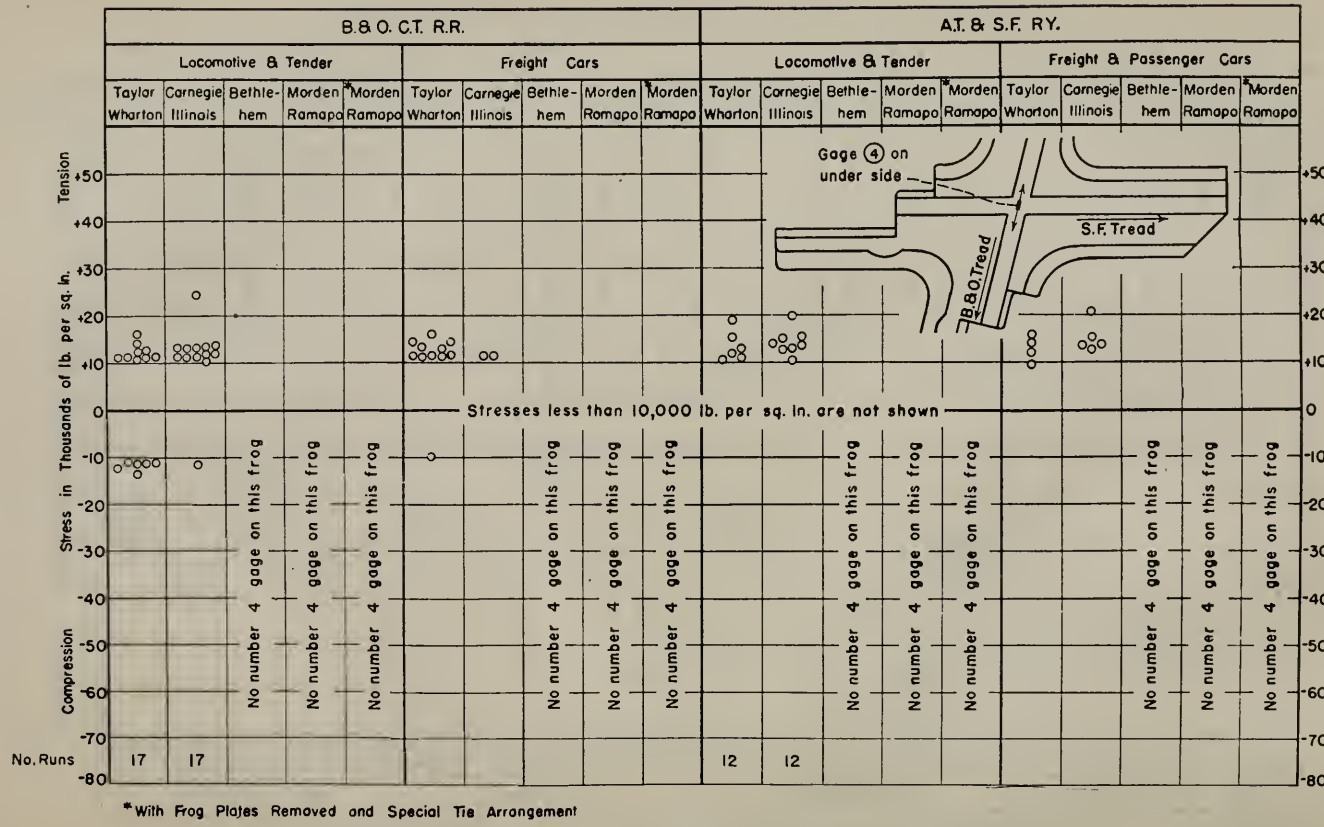
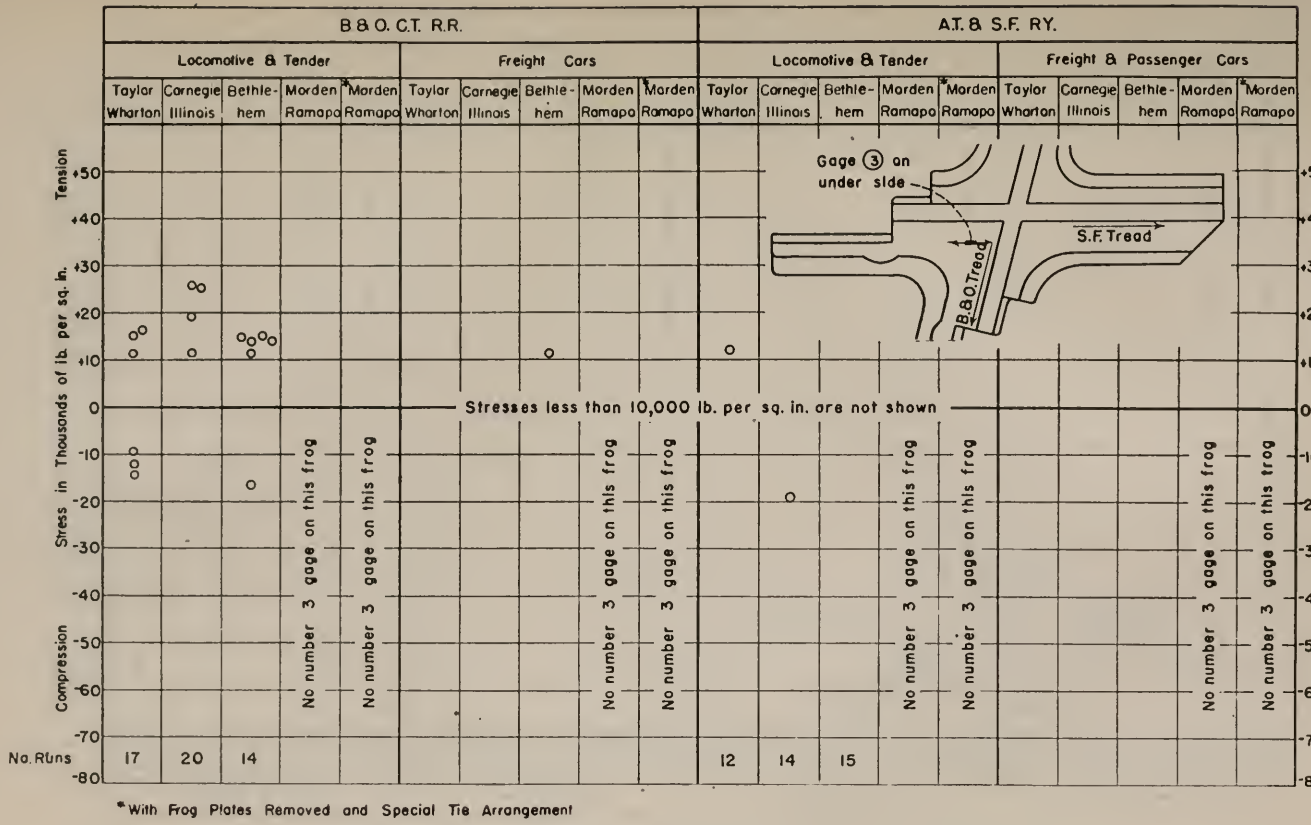


Fig. 31.—Maximum Measured Stresses in the Four Frogs. Gage No. 4.



*With Frog Plates Removed and Special Tie Arrangement

Fig. 32.—Maximum Measured Stresses in the Four Frogs. Gage No. 3.

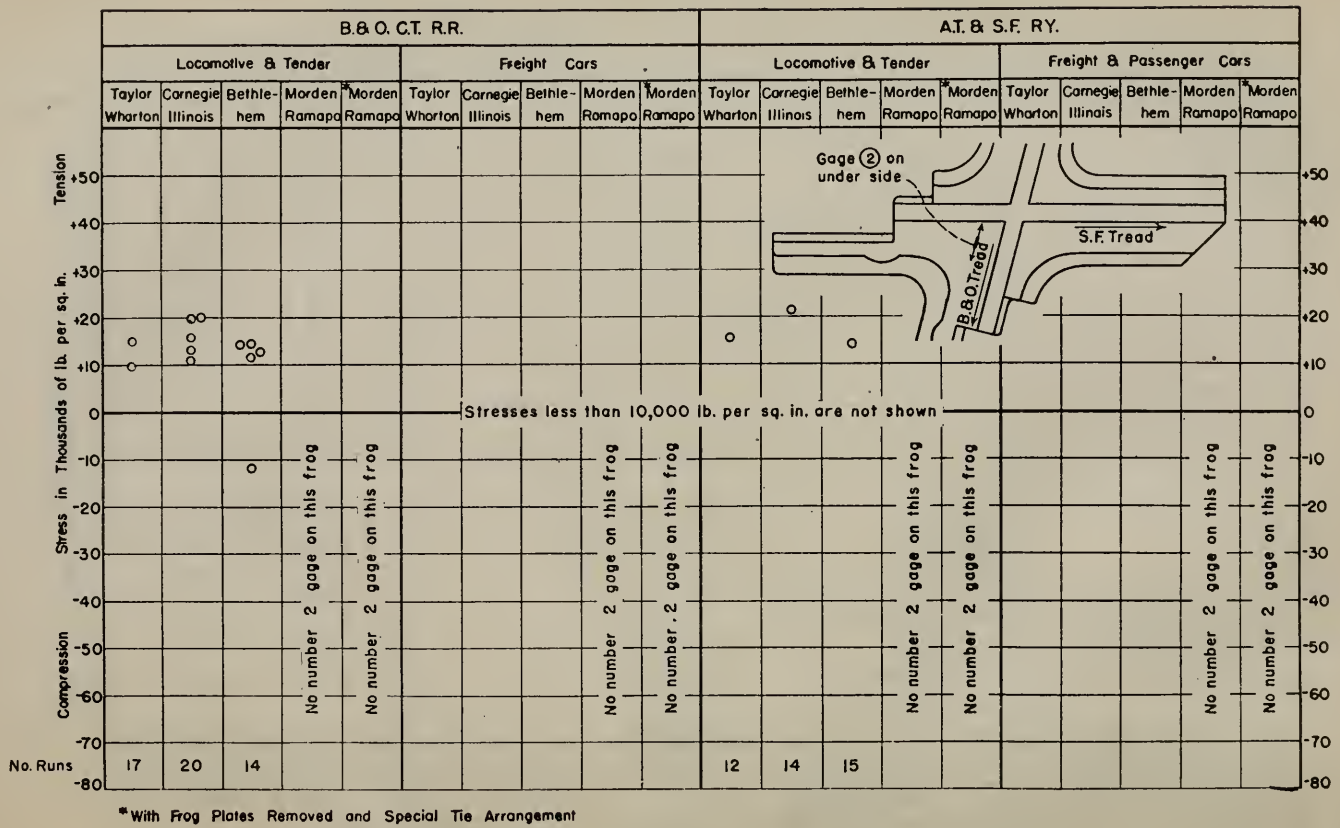


Fig. 33.—Maximum Measured Stresses in the Four Frogs. Gage No. 2.

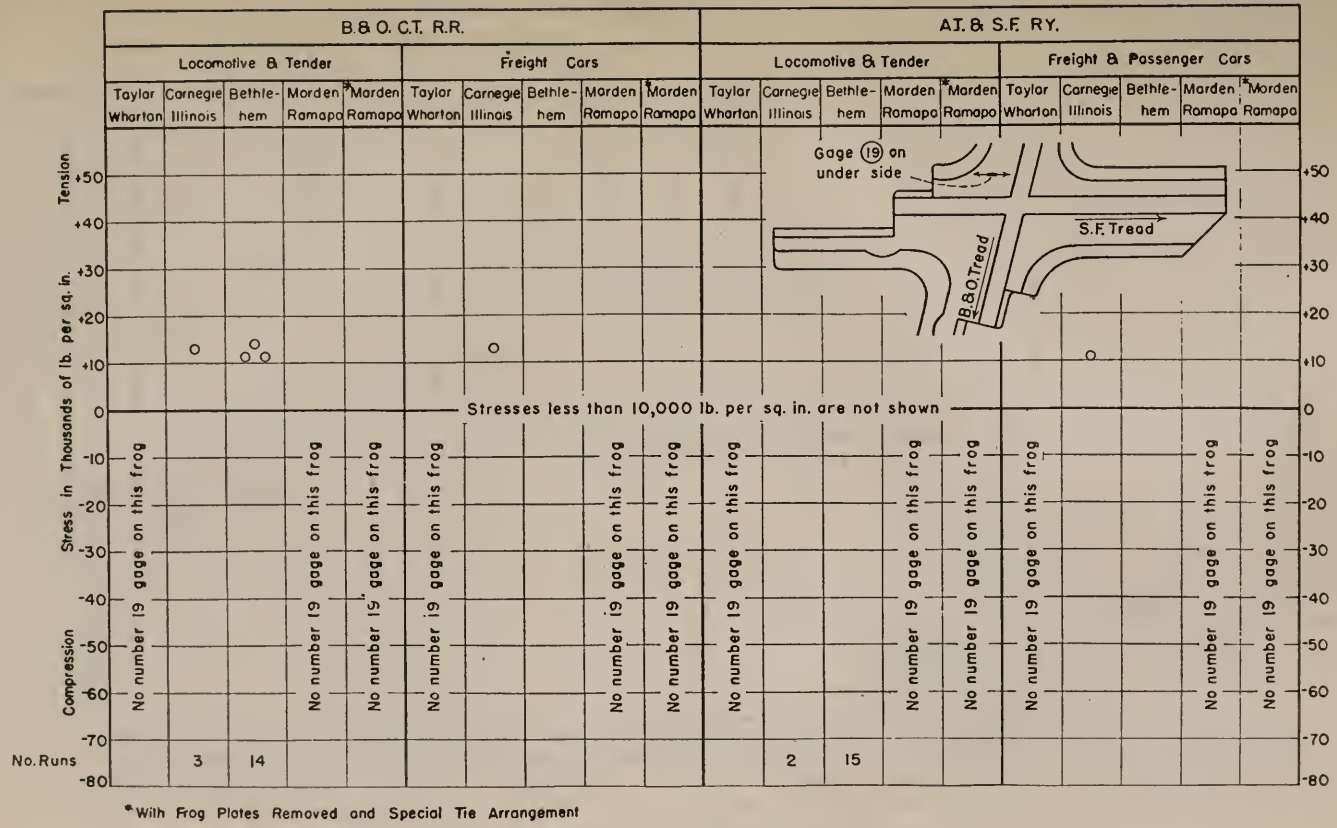
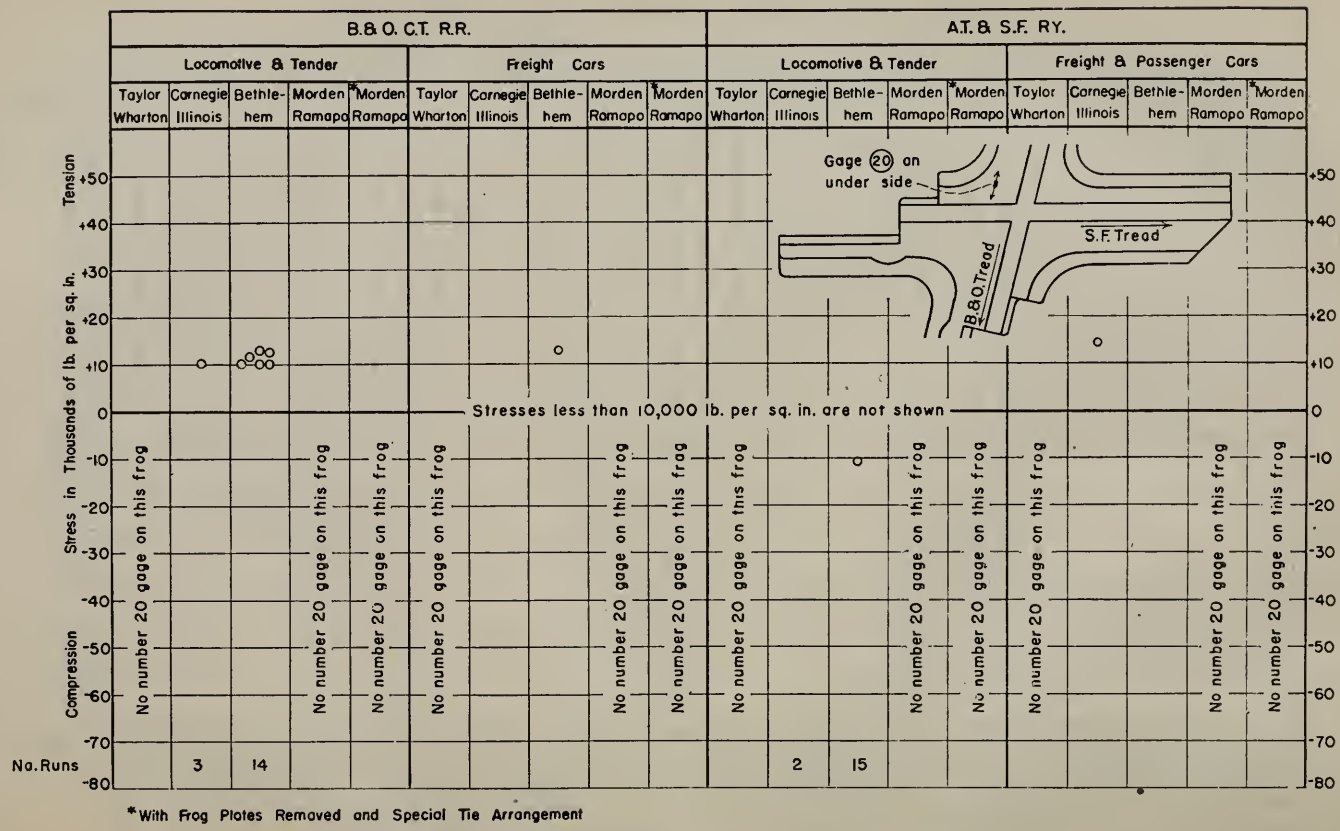


Fig. 34.—Maximum Measured Stresses in the Four Frogs. Gage No. 19.



*With Frog Plates Removed and Special Tie Arrangement

Fig. 35.—Maximum Measured Stresses in the Four Frogs. Gage No. 20.

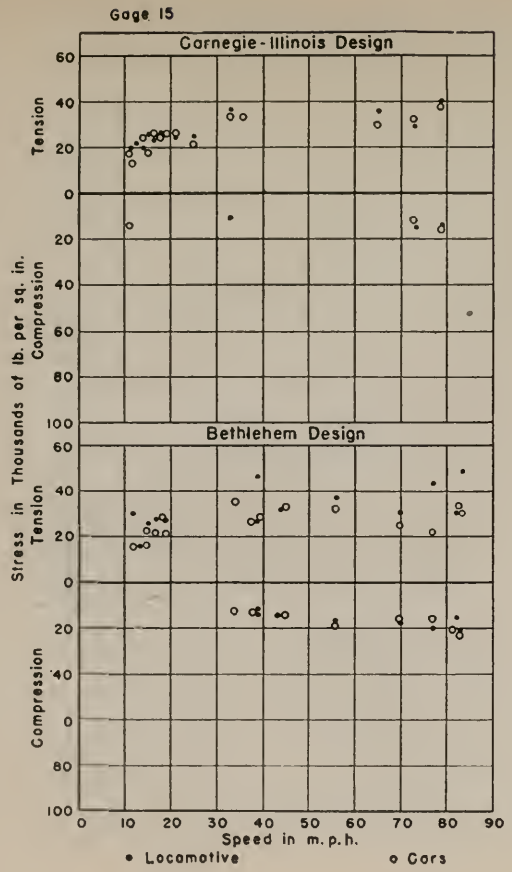
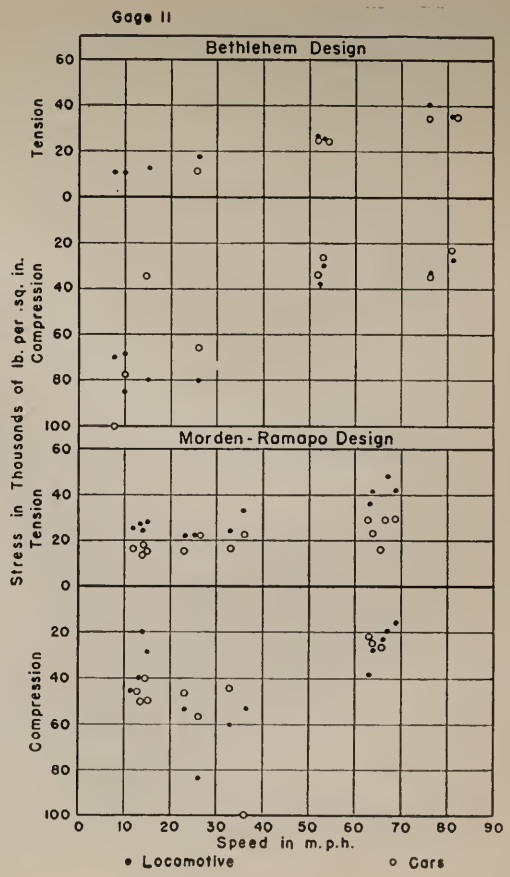


Fig. 36.—(Left) Stresses in Crossing Frogs at Various Speeds of Trains, A.T.&S.F.Ry. Traffic.

Fig. 37.—(Right) Stresses in Crossing Frogs at Various Speeds of Trains, A.T.&S.F.Ry. Traffic.



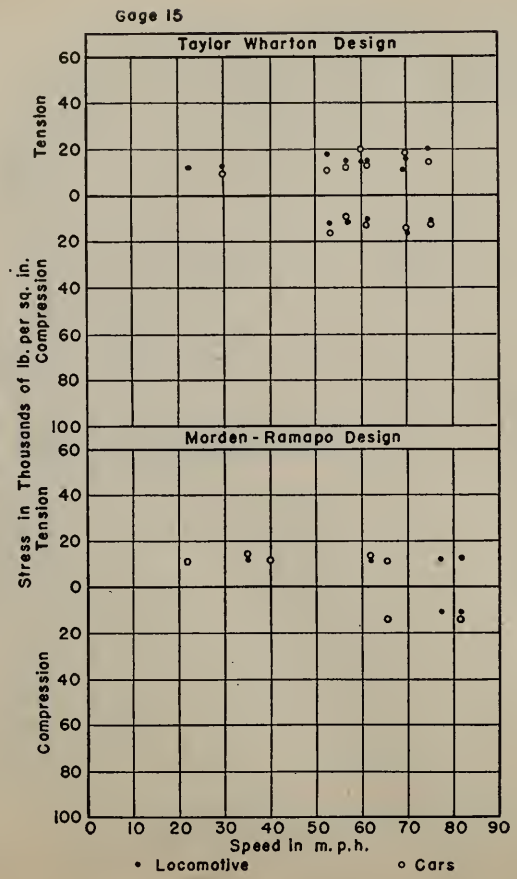
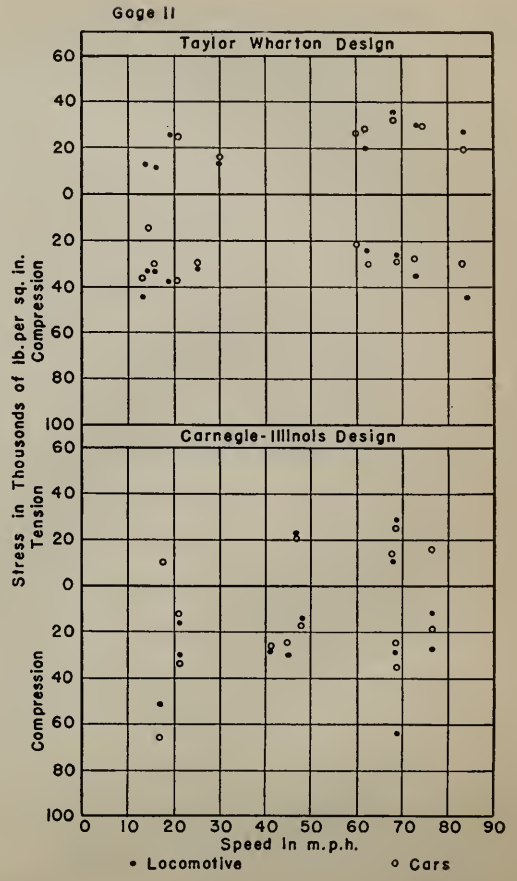


Fig. 36a.—(Left) Stresses in Crossing Frogs at Various Speeds of Trains, A.T.&S.F.Ry. Traffic.

Fig. 37a.—(Right) Stresses in Crossing Frogs at Various Speeds of Trains, A.T.&S.F.Ry. Traffic.



(text continued from page 6)

The maximum stresses at this location for the Morden–Ramapo design were greatly reduced by the revised tie layout and the removal of the base plates used in the second series of tests with this casting. (See Fig. 14).

The maximum measured stresses for the Bethlehem and Morden–Ramapo designs at gage 11 are plotted with respect to speed in Fig. 37. For both of these designs it is rather interesting to note that the maximum tension stresses show a definite tendency to increase with speed, whereas the maximum compressive stresses are quite high at low speeds and appreciably decrease with increasing speeds. It will be noted that the stresses at this gage under B.&O. traffic were quite moderate.

At gage No. 15 (Fig. 27) located at one corner of the base intersection, high tension stresses were measured with the Bethlehem and Carnegie–Illinois designs. These maximum tension stresses at this gage location are presumed, from a study of the records, to be due to impact effects as the wheels crossed the flangeway and struck the receiving side. Compressive stresses were not particularly high, but repetition of the measured maximum compressive and tension stresses a sufficient number of times might be expected to develop fatigue failures. The effect of speed on the maximum measured stresses at gage 15 in the Carnegie–Illinois and Bethlehem designs is shown in Fig. 36. There is a considerable increase in the maximum tension stresses at the higher speeds. The Taylor–Wharton and Morden–Ramapo designs which showed the lowest tension stresses at this gage location have more nearly a continuous base than the other two designs which gave the higher maximum stresses.

At gage No. 5, located at the fillet in the Santa Fe flangeway receiving the B.&O. traffic, a peak compressive stress of short duration but of high magnitude was developed when the wheel crossed the flangeway and struck the receiving face. The maximum compressive stresses were fairly high in all designs at this gage location and although the maximum tension stresses were moderate, nevertheless, the range between the tension and high compression stresses might very probably result in the development of fatigue cracks at this location.

At no other gage location were the measured stresses sufficiently high to indicate probable development of fatigue failures.

Additional Observations

At the conclusion of the tests made in December 1943 the AREA design casting was left in track. This casting was removed in August 1944, during the course of the tests described in this report, and were closely examined for cracks. It was found that a fatigue crack had developed in the fillets around the receiving corner for B.&O. traffic. It was also found that cracks had developed in the grillage supporting the flangeway floor, and that there had been a progressive increase in the size of a crack that had developed in the corner intersection corresponding to the location of gage 15 in these tests (See Fig. 38). This casting was cut with an acetylene torch and broken in order to open up the crack in the corner intersection. The extent to which this crack had progressed into the metal may be observed in the photograph.

The Morden–Ramapo design was left in its location following completion of the tests described in this report, and its condition was inspected on February 9, 1945. It was found that a line of small, disconnected cracks had begun to form in the flangeway fillets around the B.&O. receiving corner. The appearance of these cracks was typical of fatigue failure with a cycle of stress from high compression to low tension. The location of these cracks corresponds to the locations of gages 5 and 9 in these tests. The crack was longer and more pronounced at the gage 5 location. No other cracks were found in the casting.

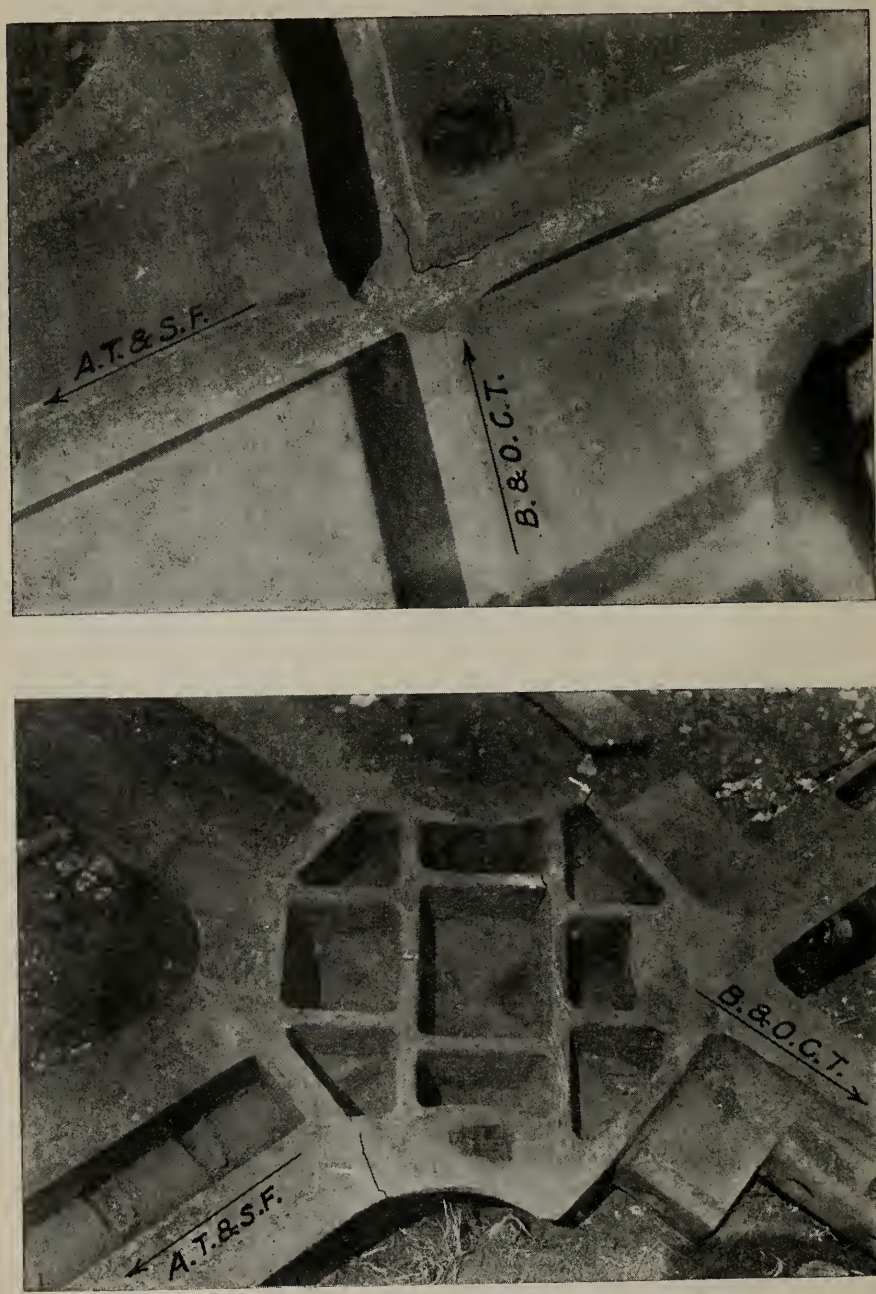


Fig. 38.—AREA Type Casting Used in Test of December 1943. Top View Shows Crack in Flangeway. Bottom View Shows Cracks in Base of Casting.

Fig. 38a.—AREA Type Casting Used in Test of December 1943. Casting Has Been Cut with Acetyline Torch and Broken in a Press to Show Extent Crack Has Progressed into Flangeway.

The remaining frogs in this crossing are of the Morden–Ramapo design and have been in service since March and May 1942. They have carried a very heavy traffic of approximately 65 trains each way daily on the B.&O. and 25 trains each way daily on the Santa Fe. Several of these frogs were examined at this same time (February 9, 1945) and it was found that in practically every casting flangeway cracks had developed in the fillet around the receiving corner in the B.&O. traffic. In one frog in addition to a well pronounced crack around the B.&O. receiving corner, a very small crack was found in the fillet around the Santa Fe receiving corner. It appears, therefore, that the stresses produced under B.&O. traffic may be more significant in the development of cracks because of the greater frequency of B.&O. train movements. After three years of heavy service the cracks had not progressed to an extent to render the castings unserviceable.

In the Bethlehem design the wedges placed to support the flangeway floor and shown in the design drawing (Fig. 4) and photograph (Fig. 10) were held in place by tack welds. When the casting was removed after a week's service practically all of the tack welds were broken and the wedges were found to be loose. It is the practice to make these wedges of manganese steel and weld them completely in place with manganese type rod, but the full welding was overlooked in the test casting.

Summary of Test Results

Study of the measured stresses obtained in the tests of the four different casting designs indicates that the range of stress is high enough at only three of the locations of measurements in some of the castings to indicate the probability of development of fatigue failures. These are at gage No. 5 located in the fillet of the Santa Fe flangeway at the B.&O. receiving corner, at gage No. 11 located in the fillet of the B.&O. flangeway at the Santa Fe receiving corner, and at gage No. 15 located at one intersection of the base flange.

At gages 5 and 11, tension stresses were produced by the upward flexing of the casting between wheels, and peak compression stresses of short duration by the impact of the wheel as it crosses the flangeway and strikes the receiving tread. As previously

stated, the stresses at location 5 are probably more significant in developing fatigue failures because of the more frequent traffic on the B.&O. and the measured stresses at this location were not greatly different for the four different casting designs, being somewhat less in tension for the Carnegie–Illinois design. The measured stresses at gage 11 under Santa Fe traffic were somewhat less with the Carnegie–Illinois and Taylor–Wharton designs and the Morden–Ramapo design with frog plates removed and the special tie arrangement.

At gage 15, high peak tension stresses were produced by the impact of the wheels on the Santa Fe receiving tread for the Carnegie–Illinois and Bethlehem designs, which do not have as continuous a base as the other two which gave lower stresses at this gage.

Conclusion

These stress measurements have served to develop information on the locations in a crossing frog where maximum stresses are developed, which information will be used as a guide in studying further improvements in crossing design and support. To continue the work on this assignment, the following program has been decided upon:

(1) Each casting is to be placed in service for one year at the original location or until batter is $\frac{3}{16}$ in. or more. The batter is to be measured from a 36-in. straight edge laid on the tread surface $\frac{3}{4}$ in. from and parallel with the gage line. The test of the Morden–Ramapo design is to begin with its installation in September 1944. For this test plates are to be omitted if possible. Each casting is to be examined after its removal and report of its condition is to be made.

(2) Further study is to be given to improvement in casting design based on the strain gage readings.

(3) A structural steel support for direct installation on rock ballast with asphaltic concrete binder is to be designed, the purpose being to provide improved support for the crossing.

Effect of the Form of Tie Plate Rail Seat on Stresses in Rail Base Flanges and Lower Web Fillets

Preliminary Report of Committee 5—Track

The report presented here covers an investigation carried out on behalf of the Committee on Track as a part of its assignment No. 6—Design of and stresses in tie plates. The subcommittee assigned to this particular subject is as follows: J. de N. Macomb (chairman, subcommittee), L. L. Adams, W. G. Arn, E. W. Backes, Blair Blowers, A. E. Botts, W. S. Boyce, E. W. Caruthers, H. R. Clarke, O. U. Cook, J. E. Fanning, H. F. Fifield, B. F. Handloser, N. M. Hench, W. G. Hulbert, C. T. Jackson, G. M. Magee, A. E. Perlman, J. A. Reed, and J. G. Wishart.

Foreword

In the tests conducted in connection with the rail design investigation of the Rail committee at Proviso, Ill., and Lathrop, Mo., as reported in the Proceedings, Vol. 46, 1945, pages 660 to 732, it was found that the combination of vertical loads with lateral thrusts produced a definite upward bending of the base, as manifested by high vertical stresses in the fillets between the base and the web. That this bending was greater directly over the tie plates than between the ties, was demonstrated by evidence of bending of the base in a longitudinal direction in the form of records of high longitudinal stresses in the top outer edge of the rail base flange. Still more noteworthy was the fact that these longitudinal bending stresses were appreciably higher in rails supported on tie plates with circular rolled crown rail seats than on tie plates with flat rail seats, indicating that the convex rail support produced a "cupping" or localized bending of the outer flange of the rail base directly over the crowned tie plate support. These stresses were much lower over tie plates with flat rail seats. The stress measurements were made only over the center of the tie plates and the question was raised whether these stresses might not be higher in the rail base directly over the edge of the rail bearing on flat seat tie plates than over the center of the plate. It was also desired to determine the effect of a beveled rolled crown rail seat, used by several railways, on these stresses.

The purpose of the laboratory tests described in this report was to obtain further information on the influence of the shape of the tie plate rail seat upon the vertical stresses in the lower rail fillets and the longitudinal flexural stresses in the rail base flanges, and thus determine the type of rail seat most favorable to stresses in the rail.

The tests were conducted by the Engineering Division research staff with funds provided by the Association of American Railroads. Randon Ferguson, electrical engineer and M. F. Smucker, assistant electrical engineer, made the stress measurements and H. E. Durham, track engineer, assisted with the laboratory work, analyzed the data, and prepared the report under the general direction of G. M. Magee, research engineer. The courtesy extended by Northwestern Technological Institute in permitting use of its laboratory facilities for the tests was particularly helpful.

Tie Plate Designs Tested

Three designs of tie plates were selected as being typical of those used in track. Tie plate branded 272, shown in Fig. 1, was 7⅝ in. wide (7½ in. nominal) by 11 in. long with shoulder thicknesses of $\frac{1}{16}$ in. and $\frac{1}{32}$ in. and a flat rail seat providing an

actual bearing surface 6⅞ in. wide. Tie plate No. 366 (having originally two transverse ribs on the bottom which were planed off for the tests) shown in Fig. 2, was 8 in. wide by 11 in. with shoulder thicknesses of $\frac{23}{32}$ in. and $\frac{19}{32}$ in. and a beveled rolled crown rail seat with the middle 5½ in. width flat. Tie plate branded 400, Fig. 3, had a circular rolled crown rail seat and was 7⅞ in. wide (7¾ in. nominal) by 11 in. long and of the same thickness as the beveled seat plate.

All of the plates had flat bottoms, double shoulders and approximately 1 to 40 cant. The flat seat plate had an eccentricity of ½ in. while in the other two it was ⅜ in. The sides of tie plate 272 with the flat rail seat were beveled somewhat on both top

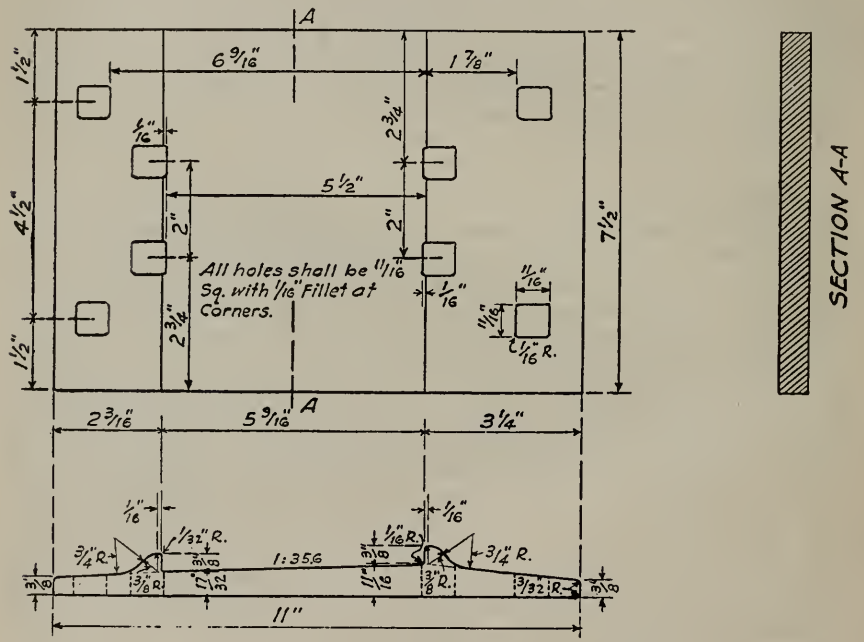


Fig. 1.—Test Tie Plate No. 272 for 112-lb. Rail.

and bottom in the shearing process. The shear drag was up on one side of the plate and down on the other but the ridge of metal left had been depressed below the rail seat by the shape of the shear blade. Prior to making the tests the rail seats of the flat and beveled seat plates were made true by milling off the surface slightly. The beveled and circular rolled crown tie plates were the same plates as those used in the tests made at Lathrop, Mo.

After the completion of these tests a profile was taken along the center line of the rail seat parallel with the shoulders of each of the three test tie plates and these profiles are shown in Fig. 3-A. A slight variation in the rail seat of the flat seat tie plate can be observed in the profile, but for all practical purposes the rail seat may be considered flat. The rail seat of the beveled tie plate was milled to a true surface and the beveled portions were ground off to restore the seat to a width of 5½ in. In the grinding process the corners were rounded slightly. No machining was done on the circular rolled

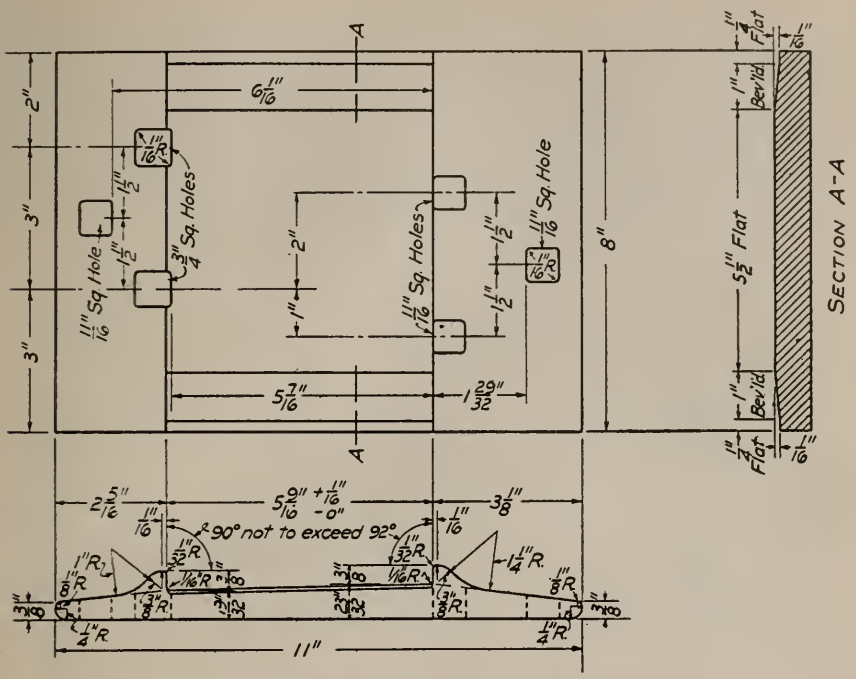


Fig. 2.—Test Tie Plate No. 366 for 112-lb. Rail.

crown tie plate but it had previously been used in the Lathrop, Mo., tests for a short period. The convex surface of this tie plate was actually 6 in. wide instead of 7¼ in. as shown in the design drawing, Fig. 3.

Test Rail Assembly

These tests were made in the laboratory so that all conditions could be closely controlled and reliable comparisons could be made. However, it was necessary to provide conditions for the test so the "wave action" effect of the rail in track could be duplicated. This required the use of a relatively long rail supported on several ties, with the ties resting on a suitable material which would provide the elasticity of the roadbed. Preliminary tests showed that a 2-in. thickness of Celotex would be suitable for this purpose.

Arrangements were made with Professor G. A. Maney for the use of the 1,000,000-lb. capacity Southwark–Emery testing machine in the civil engineering laboratory of the Northwestern Technological Institute at Evanston, Ill. This machine was most suitable since the test rail assembly could be placed on the steel and concrete floor and the load could be applied at any point on top of the rail by shifting the rail assembly on the floor.

The rail assembly consisted of a 112-lb. RE rail, 19½ ft. long, supported by 11 yellow pine ties, 6 in. by 8 in. by 18 in. long, spaced on 21-in. centers, all of which rested upon a continuous mat of Celotex 2 in. in thickness and 24 in. wide. The three test plates were placed in succession on the middle tie and a 40,000-lb. vertical load was

applied on the center of the rail head over the middle of the test tie plate; then over the east edge of the contact between the rail base and the tie plate seat (see sketches in Table 1); then at a point half way between the middle tie and the next one to the east, and lastly over the middle of the next tie to the east. This succession of loads was applied to the rail laid on the 1 to 40 cant of the tie plates which developed a 1000-lb. lateral inward component force and also with the rail supported on ties and tapered blocks to give it an outward slope of 1 to 4 less the cant of the tie plates, thus pro-

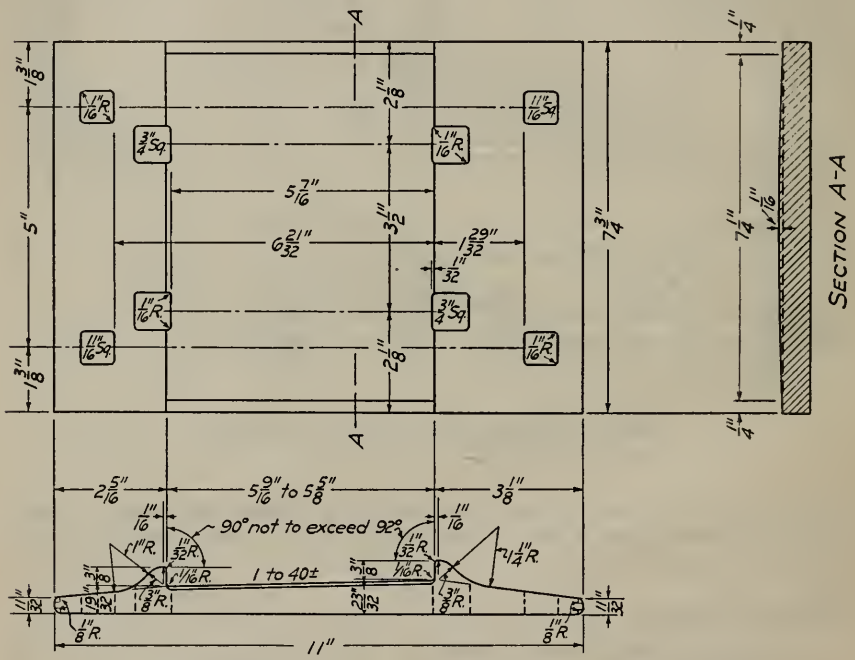


Fig. 3.—Test Tie Plate No. 400 for 112-lb. Rail.

ducing a combination of a 40,000-lb. vertical load with a 9000-lb. lateral component force toward the outer shoulder of the tie plates. Figs. 4 and 5 show the test rail assembly for the 1 to 40 and 1 to 4 inclinations, respectively. In Fig. 6 is shown the detail of the loading arrangement on the rail. With this method the 40,000-lb. load was applied precisely the same for each test plate and each position along the rail.

Stresses Measured

It was determined from the static tests at Proviso, Ill. and the dynamic stresses measured in the rail at Lathrop, Mo., that high localized stresses occur in the lower rail fillets and base flanges over the tie plates, and that the shape of the tie plate rail seat greatly influenced the magnitude of these stresses. Furthermore, the stresses in the upper rail fillets and upper portion of rail web were found to be directly related to the magnitude of the vertical load and the eccentricity of the loading on the rail head, and were little affected by lateral loads on the rail and not materially different when meas-

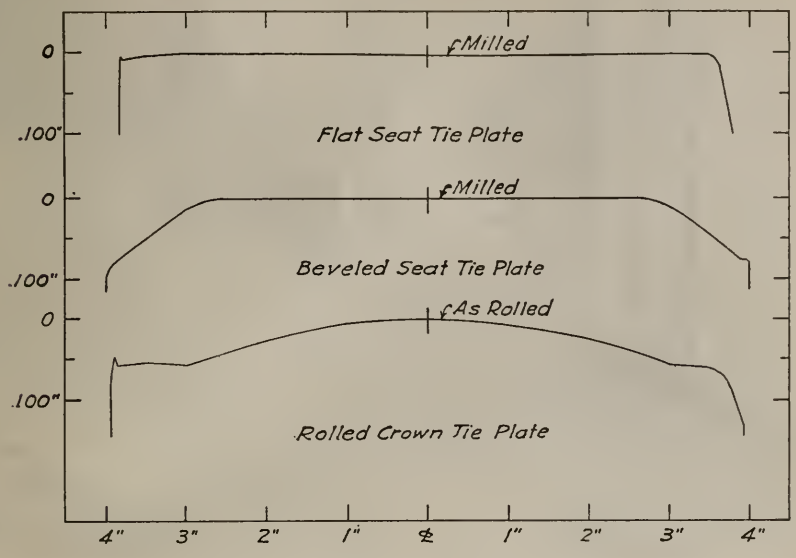


Fig. 3-A.—Profiles of Tie Plate Rail Seats.

ured over or between ties. Therefore, a comprehensive investigation of this subject can be carried out in the laboratory by measurement of the lower rail fillet stresses in a vertical plane, of the longitudinal bending stresses along the top edge of the rail base flange, and of the flexural stresses in the bottom of the tie plates.

Some SR-4 electrical type wire resistance strain gages were applied to the rail and to the three designs of tie plates as shown in the figure in Table 1. The nine wire gages and wiring on the bottom of the rolled crowned tie plate are shown also in Fig. 7. All of the strain gages were of ½-in. length except the ten on the lower rail fillets which were ¼ in. in length. Nine gages were placed on each of the test tie plates and all of these except gages 4 and 6 were used to measure the bending strains parallel with the length of the tie plate. Gages 4 and 6 measured strains transversely with the tie plate. Five gage lines were established on the rail to measure the distribution of the stresses in the lower rail fillets and rail base flanges. One gage line was placed over the center line of the tie plate parallel with its length. Two lines of gages were placed 5½ in. apart and directly over the edges of contact between the rail base and the beveled tie plate rail seat. The two lines of gages 6⅞ in. apart conformed to the actual width of the rail bearing of the flat seat plate No. 272. Another line of gages for only the flange stresses was located 2 in. east of the outer gage line over the test tie plates. To ascertain maximum rail stresses, the 40,000-lb. load was placed over the middle of the three designs of tie plates and over the east edges of contact between the rail base and rail seat for the beveled and flat seat plates only.

The strains developed by the wire resistance gages were measured with the Baldwin-Southwark SR-4 portable strain indicator as shown in the extreme right portion of Fig. 5. This apparatus is described in the report covering the Proviso Test, Proceedings, Vol. 46, 1945, pages 663 to 668.

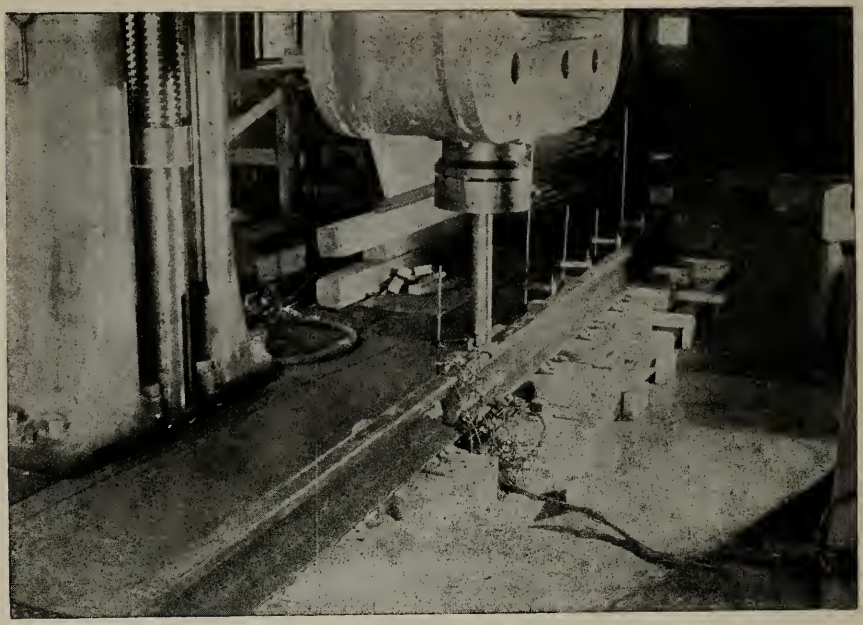


Fig. 4.—Test Rail Assembly with the Rail on a 1 to 40 Cant.

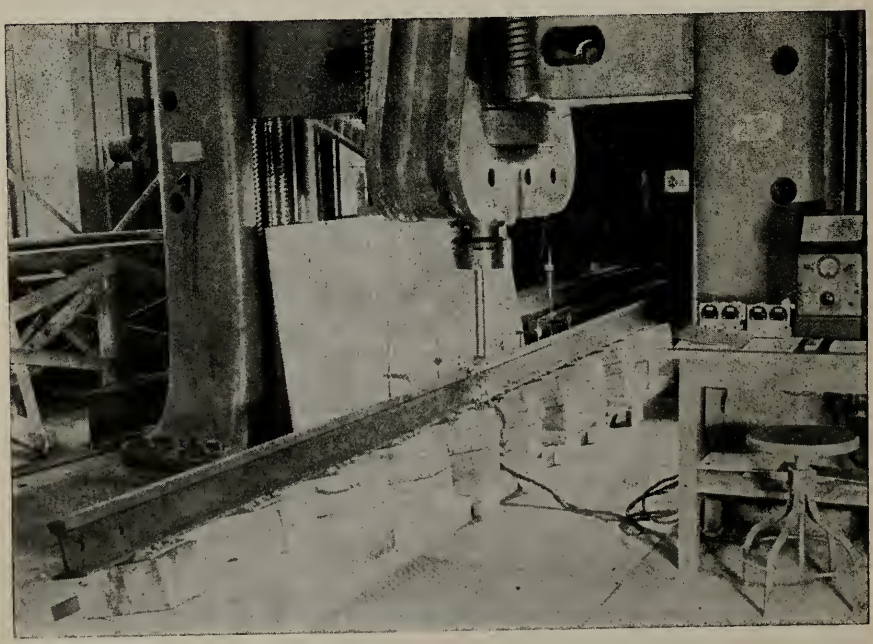


Fig. 5.—Test Rail Assembly with the Rail on a 1 to 4 Outward Slope.

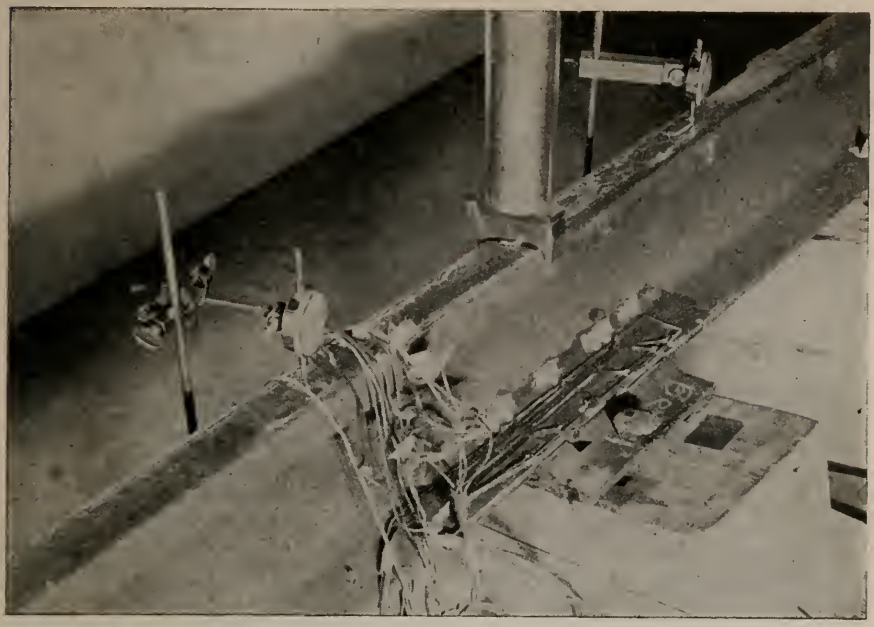


Fig. 6.—View of Arrangement for Loading the Test Rail and Wire Gages on the Gage Side of the Rail.

Fig. 7.—Bottom of Tie Plate Showing Wire Gages and Wiring.

Depression of the Rail

By means of five Ames dials attached to metal stands clamped to platforms straddling the Celotex mat, the depressions of the rail were measured to determine the characteristics of the elastic foundation. The arrangement of the dials can be observed in Figs. 4, 5 and 6. The rail depression near the point of load application averaged ⅛ in. for the 40,000-lb. load and after the first few applications of load the rail would spring back to within 0.01 in. of its original level, indicating very little loss in elasticity of the Celotex mat and good uniformity of rail depression throughout the test. Rail depressions were also measured by increments of 10,000 lb. up to a maximum load of 40,000 lb., and these data indicated a moderate deviation of the load-depression curve from a straight line. The mean modulus of elasticity of rail support between applied loads of 10,000 and 40,000 lb. was 1600 lb. per in. of rail length per inch of depression, a value comparable to moderately stiff track.

Discussion of the Test Data

The measured stresses in the rail and tie plates are shown in Table 1, Part 1, covering the loading of the rail on the 1 to 40 cant and Part 2, covering the 1 to 4 inclination of the ties which produced the effect of a 9000-lb. lateral component force in combination with the 40,000-lb. vertical load. In Part 1 of the table, the maximum longitudinal tensile stress in the rail base flanges was 27,700 lb. per sq. in. for the rolled crown plate, and 26 to 28 percent lower maximum values were obtained over the other two tie plates. Maximum compressive stresses in the lower rail fillets were 11,600, 16,900 and 20,400 lb. per sq. in. for the flat, beveled and circular rolled crown tie plates, respectively. All of the foregoing maximum localized stresses were recorded in the rail over the longitudinal center line of the tie plates, except in the case of the flat seat tie plate. Over that tie plate the maximum rail flange stress was recorded at the gage line ¾ in. from the east edge of the contact between the rail base and the tie plate. In Part 2 of Table 1 the condition of loading recorded was more severe and produced higher stresses in the rail.

Maximum stress values, as would be expected, were developed in the outer rail flange and fillet and are given below in units of 1000 lb. per sq. in. (The minus sign denotes a compressive stress)

	Rail Base Flange Stresses			*Lower Fillet Stresses*		
	Flat seat	*Beveled rolled seat*	*Circular rolled crown*	*Flat seat*	*Beveled rolled seat*	*Circular rolled crown*
Stress	26.3	30.8	42.9	—17.2	—22.2	—23.5
Percent	100.	117.	163.	100.	129.	137.

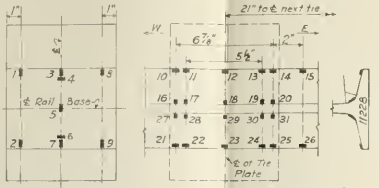
The above comparison definitely shows that the circular rolled crown tie plate rail seat has the most unfavorable effect as to rail stresses and that the flat seat tie plate appears to have an advantage over the beveled seat plate. A graphical comparison of the maximum stress concentrations in each of the rail base flanges for the six gage lines and two arrangements of loading the rail assembly is shown in Fig. 8. From Table 1 it will be noted that the maximum rail stresses over the flat seat plate for the several positions of load and rail inclinations rarely occurred over the edge of the rail base contact with the tie plate.

For all test conditions, the tie plate stresses were of moderate magnitude. These values for the beveled tie plate were generally more favorable than for the other two designs, especially for the 1 to 40 cant tests in which the maximum stress was 7200 lb.

SSES IN 112-LB. TIE PLATES AND RAIL SECTION NO. 11228 AT THE CIVIL — Table 1

RY OF THE NORTHWESTERN TECHNOLOGICAL INSTITUTE, EVANSTON, ILLINOIS. — Part 1

made with a 19½ foot rail supported by eleven 6" x 8" - 18" yellow pine
mat of Celotex, 2 in. thick.



Position of Gages on Bottom of Tie Plates - Top View

Position of Gages on Rail Flanges and Lower Fillets

MEASURED STATIC STRESSES IN 112-LB. TIE PLATES AND RAIL SECTION NO. 11228 AT THE CIVIL ENGINEERING LABORATORY OF THE NORTHWESTERN TECHNOLOGICAL INSTITUTE, EVANSTON, ILLINOIS. Table 1 Part 1

Note: This test was made with a 1½ foot rail supported by eleven 6" x 8" - 18" yellow pine ties on a continuous mat of Celotex, 2 in. thick.

Load: 40,000 lb. Stresses are shown to 1,000 lb. per sq. in. Compressive stresses are indicated by a minus sign.

1:40 Cant (40,000 lb. vertical load with 1,000 lb. horizontal inward component force)

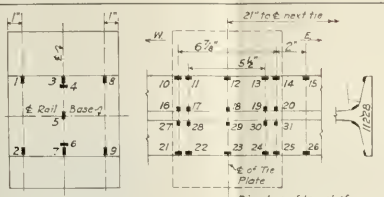
Gage No.	Gage Position	Load Over Middle of Test Tie Plates			Load Over Seat Edge of Contact Between Rail Base and Test Tie Plates		Load Half Way Between Ties, 10½ in. East of Middle of Test Tie Plates			Load 21 in. East of Test Tie Plates, over Middle of Next Tie		
		(1) Flat Rail Seat	(2) Beveled Rail Seat	(3) Rolled Crown Seat	(4) Flat Rail Seat	(5) Beveled Rail Seat	(6) Flat Rail Seat	(7) Beveled Rail Seat	(8) Rolled Crown Seat	(9) Flat Rail Seat	(10) Beveled Rail Seat	(11) Rolled Crown Seat
	On Bottom of Tie Plates:											
1	Outer shoulder 1 in. from west edge	1.6	3.2	4.7	1.3	3.2	1.6	2.5	4.2	1.4	1.9	3.4
2	Gage shoulder 1 in. from west edge	13.1	-0.1	8.0	11.7	-0.5	11.5	-0.9	7.3	9.3	-0.5	6.2
3	Outer shoulder along center line of plate	4.3	4.6	7.0	5.4	4.7	4.6	4.0	6.7	3.7	3.3	5.2
4	Outer shoulder along center line of plate, transverse	-1.4	4.8	7.8	1.3	4.6	-2.5	3.4	7.9	-2.1	2.7	6.0
5	Middle of rail seat along center line	1.1	3.2	-2.5	0.9	2.9	1.2	2.5	-2.8	1.3	2.2	-2.8
6	Gage shoulder along center line, transverse	-3.6	7.2	8.9	-3.8	6.7	-4.7	5.1	8.3	-4.3	3.4	7.4
7	Gage shoulder along center line	14.3	5.0	12.8	12.6	3.7	12.4	4.0	12.2	9.4	3.6	11.0
8	Outer shoulder 1 in. from east edge	4.9	3.7	2.8	4.7	3.9	5.6	3.4	2.6	4.3	3.3	1.9
9	Gage shoulder 1 in. from east edge	9.8	2.1	2.4	9.6	2.2	9.7	3.6	2.2	8.3	4.4	5.2
	On Outer Rail Flange over:											
10	West edge of rail bearing on flat seat plate	15.8	14.4	13.5	13.3	13.3	10.3	8.3	8.0	5.8	5.0	4.4
11	West edge of rail bearing on beveled seat plate	15.4	14.2	12.7	13.7	13.3	10.3	8.1	7.6	6.1	4.6	4.0
12	Center line of plate	16.7	16.4	27.7	15.3	18.3	11.5	12.2	24.1	6.8	7.2	15.6
13	East edge of rail bearing on beveled seat plate	17.3	14.1	14.0	18.0	14.8	16.0	10.6	11.1	10.5	6.0	5.8
14	East edge of rail bearing on flat seat plate	15.3	13.7	14.3	15.5	14.6	14.0	11.0	12.5	8.5	5.8	6.7
15	2 in. east of gage No. 14	14.7	14.3	14.8	15.6	15.8	14.4	13.6	15.2	8.6	7.9	8.8
	On Lower Outer Fillet over:											
16	West edge of rail bearing on flat seat plate	-4.4	-4.2	-4.0	-3.2	-3.6	-3.1	-2.1	-2.7	-1.8	-0.8	-1.4
17	West edge of rail bearing on beveled seat plate	-5.9	-6.2	-6.5	-4.3	-5.2	-4.2	-3.2	-4.4	-2.5	-1.3	-2.5
18	Center line of plate	-8.1	-10.6	-13.4	-6.8	-10.1	-6.0	-7.6	-11.3	-4.0	-5.2	-8.6
19	East edge of rail bearing on beveled seat plate	-7.1	-5.8	-3.4	-8.4	-7.4	-7.6	-5.2	-4.4	-5.6	-4.1	-3.3
20	East edge of rail bearing on flat seat plate	-6.5	-5.3	-4.5	-7.5	-6.5	-6.1	-4.1	-3.3	-4.6	-3.4	-2.5
	On Inner Rail Flange over:											
21	West edge of rail bearing on flat seat plate	20.9	15.3	14.3	17.4	13.2	12.4	9.0	8.1	7.4	4.5	4.5
22	West edge of rail bearing on beveled seat plate	21.2	15.4	13.7	18.6	13.1	12.9	8.8	7.7	8.7	4.3	4.1
23	Center line of plate	19.9	21.6	27.6	18.1	19.9	12.7	15.2	22.6	7.5	8.5	16.0
24	East edge of rail bearing on beveled seat plate	22.0	16.5	14.1	21.6	16.8	17.5	17.9	11.2	11.5	12.3	5.8
25	East edge of rail bearing on flat seat plate	20.3	15.4	15.1	20.7	15.5	17.6	13.8	12.9	11.8	7.6	7.2
26	2 in. east of gage No. 20	18.4	16.0	16.0	18.6	16.6	17.0	15.4	16.3	10.7	8.5	10.2
	On Lower Inner Fillet over:											
27	West edge of rail bearing on flat seat plate	-9.0	-6.4	-6.6	-7.2	-5.2	-6.0	-3.9	-4.7	-4.2	-2.4	-2.8
28	West edge of rail bearing on beveled seat plate	-10.6	-8.2	-8.8	-8.7	-6.7	-7.4	-5.2	-6.5	-5.4	-3.4	-4.1
29	Center line of plate	-11.6	-16.4	-20.4	-14.0	-15.4	-7.8	-13.6	-17.5	-5.4	-10.0	-14.3
30	East edge of rail bearing on beveled seat plate	-9.4	-8.9	-7.0	-11.0	-10.2	-9.3	-11.3	-7.0	-7.0	-10.9	-6.0
31	East edge of rail bearing on flat seat plate	-8.2	-7.0	-5.4	-10.2	-8.4	-9.0	-9.5	-5.9	-6.8	-8.7	-4.8

SES IN 112-LB. TIE PLATES AND RAIL SECTION NO. 11228 AT THE CIVIL — Table 1

Y OF THE NORTHWESTERN TECHNOLOGICAL INSTITUTE, EVANSTON, ILLINOIS — Part 2

made with a 19½ foot rail supported by eleven 6" x 8" - 18" yellow pine
mat of Celotex, 2 in. thick.

resses are shown in 1,000 lb. per sq. in. Compressive stresses are indicated



Position of Gages on Bottom of Tie Plates - Top View

Position of Gages on Rail Flanges and Lower Fillets

MEASURED STATIC STRESSES IN 112-LB. TIE PLATES AND RAIL SECTION NO. 11228 AT THE CIVIL ENGINEERING LABORATORY OF THE NORTHWESTERN TECHNOLOGICAL INSTITUTE, EVANSTON, ILLINOIS

Teble 1
Part 2

Note: This test was made with a 19½ foot rail supported by eleven 6" x 8" - 18" yellow pine ties on a continuous mat of Celotex, 2 in. thick.

Load: 40,000 lb. Stresses are shown in 1,000 lb. per sq. in. Compressive stresses are indicated by a minus sign.

1 to 4 Outward slope (40,000 lb. vertical load with 9,000 lb. horizontal outward component force).

		Load Over Middle of Test Tie Plates			Load Over East Edge of Contact Between Rail Base and Test Tie Plates		Load Half Way Between Ties, 10½ in. East of Middle of Test Tie Plates			Load 21 in. East of Test Tie Plates, over Middle of Next Tie		
Gage No.	Gage Position	(12) Flat Rail Seat	(13) Beveled Rail Seat	(14) Rolled Crown Seat	(15) Flat Rail Seat	(16) Beveled Rail Seat	(17) Flat Rail Seat	(18) Beveled Rail Seat	(19) Rolled Crown Seat	(20) Flat Rail Seat	(21) Beveled Rail Seat	(22) Rolled Crown Seat
	On Bottom of Tie Plates:											
1	Outer shoulder 1 in. from west edge	9.1	5.6	6.7	7.5	5.0	3.4	4.0	4.6	1.0	3.2	2.3
2	Gage shoulder 1 in. from west edge	6.3	-0.9	4.7	7.3	-0.8	7.4	-0.3	3.2	6.6	-0.5	2.7
3	Outer shoulder along center line of plate	11.1	11.5	12.8	13.5	10.9	7.5	8.9	9.9	5.7	7.3	5.5
4	Outer shoulder along center line of plate, transverse	0.2	4.4	10.2	-0.5	3.5	0.9	2.2	7.6	-2.6	1.4	4.7
5	Middle of rail seat along center line	0.3	4.4	-3.5	0.3	4.4	0.6	4.4	-4.0	1.4	3.3	-3.9
6	Gage shoulder along center line, transverse	-2.3	3.7	6.9	-3.0	2.7	-3.6	2.2	6.1	-3.7	1.6	4.6
7	Gage shoulder along center line	6.5	0.5	8.0	6.9	0.4	7.4	0.4	7.5	6.8	0.2	6.3
8	Outer shoulder 1 in. from east edge	9.1	13.6	5.2	9.3	14.5	8.8	13.9	4.7	7.3	12.2	2.9
9	Gage shoulder 1 in. from east edge	4.2	0.5	1.0	4.4	0.6	5.4	0.5	4.0	6.6	0.5	1.2
	On Outer Rail Flange over:											
10	West edge of rail bearing on flat seat plate	24.7	22.7	20.8	20.9	20.4	21.7	13.4	11.4	6.5	5.1	5.7
11	West edge of rail bearing on beveled seat plate	24.3	22.5	20.0	20.9	20.4	14.1	13.4	10.8	6.5	5.0	5.2
12	Center line of plate	26.2	29.0	42.9	24.6	26.2	18.4	17.5	27.2	8.1	6.8	11.4
13	East edge of rail bearing on beveled seat plate	26.0	29.7	19.5	26.3	30.8	24.7	22.7	14.6	15.7	20.0	7.6
14	East edge of rail bearing on flat seat plate	21.6	21.3	19.7	22.3	21.3	19.7	18.2	16.0	11.2	12.2	8.8
15	2 in. east of gage No. 14	20.6	21.1	21.1	22.1	22.0	21.1	20.1	20.5	11.9	10.0	12.6
	On Lower Outer Fillet over:											
16	West edge of rail bearing on flat seat plate	-9.5	-8.3	-8.4	-8.3	-6.2	-4.0	-3.2	-3.5	-1.1	-1.2	-1.1
17	West edge of rail bearing on beveled seat plate	-13.7	-11.0	-11.1	-10.6	-8.4	-5.4	-4.3	-5.7	-1.9	-2.2	-2.6
18	Center line of plate	-16.6	-20.0	-23.5	-14.5	-17.9	-9.4	-11.6	-17.8	-4.9	-8.2	-11.0
19	East edge of rail bearing on beveled seat plate	-15.3	-19.4	-12.5	-17.2	-22.2	-14.1	-18.1	-11.4	-9.8	-14.7	-7.7
20	East edge of rail bearing on flat seat plate	-12.4	-15.1	-9.8	-13.9	-17.1	-10.0	-12.9	-8.8	-6.9	-10.2	-4.1
	On Inner Rail Flange over:											
21	West edge of rail bearing on flat seat plate	7.0	6.2	8.2	7.1	5.4	6.9	3.6	3.7	6.9	3.2	3.3
22	West edge of rail bearing on beveled seat plate	7.7	5.9	6.2	7.4	5.3	6.3	3.4	3.2	6.8	3.0	3.1
23	Center line of plate	6.2	7.4	15.9	6.2	6.7	5.0	4.1	12.3	4.9	3.6	7.3
24	East edge of rail bearing on beveled seat plate	7.8	5.3	5.3	8.4	6.4	8.2	4.5	3.1	8.0	4.5	1.8
25	East edge of rail bearing on flat seat plate	7.1	5.0	6.2	7.8	5.4	7.6	3.5	4.2	7.0	2.6	2.4
26	2 in. east of gage No. 25	6.7	6.0	7.3	7.7	6.6	7.5	5.2	6.7	5.7	3.2	4.1
	On Lower Inner Fillet over:											
27	West edge of rail bearing on flat seat plate	-2.5	-1.0	-1.3	-2.8	-0.7	-3.4	-0.7	-1.0	-2.7	-0.8	-0.9
28	West edge of rail bearing on beveled seat plate	-3.0	-1.2	-2.3	-3.2	-0.7	-3.7	-1.0	-1.7	-2.9	-0.9	-1.4
29	Center line of plate	-3.3	-5.8	-11.4	-2.8	-5.0	-3.4	-4.5	-10.6	-2.9	-4.8	-9.7
30	East edge of rail bearing on beveled seat plate	-2.0	-1.9	-2.9	-3.0	-4.0	-3.8	-3.4	-3.3	-5.0	-4.5	-4.6
31	East edge of rail bearing on flat seat plate	-1.6	-1.3	-1.5	-2.7	-3.1	-3.2	-2.5	-1.9	-4.4	-3.4	-2.9

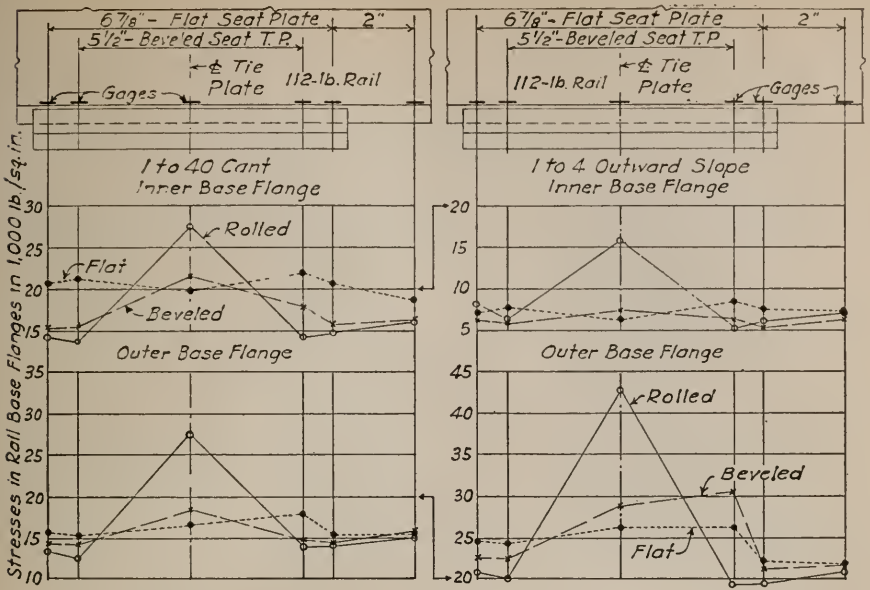


Fig. 8.—Comparison of Maximum Longitudinal Tensile Stresses in Rail Base Flanges When Resting on Tie Plates with Flat, Bevelled and Rolled Crown Rail Seats—40,000-lb. Static Load.

per sq. in. as compared to 12,800 and 14,300 lb. per sq. in. for the circular rolled crown and flat seat plates, respectively. In the tests with the rail inclined on the 1 to 4 slope the highest stress measured in the three tie plates ranged from 12,800 to 14,500 lb. per sq. in.

Conclusions

1. Longitudinal rail base flange stresses are considerably greater and the lower rail fillet stresses are moderately larger with the rail resting on the circular rolled crown seat than when flat seat or beveled seat tie plates are used.

2. Rail stresses were somewhat lower over the flat seat tie plate than over the beveled seat plate.

3. For minimizing localized stresses in the rail base and lower fillets over the tie plate, it may be concluded that the rail seat should be flat over as much of the tie plate width as possible. Provision should be made for a sufficient bevel or depression at the sides of the plate to avoid the sheared edge contacting the rail base.

Report of Committee 16—Economics of Railway Location and Operation

M. F. Mannion, *Chairman,*
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E. Y. Allen
B. T. Anderson
J. W. Barriger
C. H. Blackman
V. T. Boughton
C. W. Breed
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H. M. Stout*
J. E. Teal
F. C. Teske
V. P. Turnburke
H. D. Walker
H. P. Weidman
J. A. Wood
J. S. Worley
Committee

* Died June 16, 1945.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions..... page 51

2. Methods for obtaining a more intensive use of existing railway facilities.

   No report.

3. Methods or formulas for the solution of special problems relating to more economical and efficient railway operation.

   Progress report, submitted as information..... page 52

4. Effect of higher speed on railway revenues, operating expenses, and charges to capital account.

   No report.

5. Economics of railway location and operation as affected by railway electrification, collaborating with Electrical Section, Engineering Division, AAR.

   Progress report, submitted as information..... page 54

6. Development of modern power units and the effects on the economics of railway location and operation.

   No report.

7. The general course of the cost of railway transportation and operation over the past 100 years, the principal determining elements and the economic significance.

   No report.

AREA Bulletin 455, November 1945.

8. Coordinated highway service and its effect on the economies of railway operation.

No report.

9. Economics of operation of union railway passenger terminals.

No report.

THE COMMITTEE ON ECONOMICS OF RAILWAY LOCATION, AND OPERATION,

M. F. MANNION, *Chairman.*

Howard M. Stout

The Committee on Economics of Railway Location and Operation takes this opportunity to express the deep regret occasioned by the death on June 16, 1945, of one of its members and a former chairman, Howard M. Stout, retired valuation engineer of the Northern Pacific Railway.

Howard M. Stout was born at New London, Ind., on July 31, 1873, the son of John and Mary (Morris) Stout. He obtained his preliminary education in the public schools at New London; was graduated from Earlham college with the degree of Ph.B. in 1896; attended graduate school of University of Chicago, 1898, 1900, 1901 and 1903, and Columbia University School of Engineering in 1902. During his college career he was employed as draftsman, and also engaged in geological field examination work in Indiana. He was instructor in civil engineering at Worcester Polytechnic Institute from 1903 to 1906 and entered railroad work in 1905 as assistant engineer on reconstruction on the Chatham division of the Rutland Railroad. In 1906 Mr. Stout went to the Northern Pacific Railway as assistant engineer on terminal construction and later that year transferred to the Spokane, Portland & Seattle Railway as assistant engineer on the construction of new lines. He remained there until 1908 when he returned to the Northern Pacific with which he served 35 years as engineer on location, construction, cost analyses and valuation work, residing in Minneapolis. He was appointed assistant valuation engineer September 16, 1930, and was advanced to valuation engineer October 1, 1941, retiring from that position July 31, 1943.

Mr. Stout was elected to membership in American Railway Engineering Association in 1907, became a Life Member in 1942, and participated in committee work from 1915 until his death, serving as member and chairman of the following committees:

Committee 11—Records and Accounts, 1915–1926; chairman the last five years.
Committee 22—Economics of Railway Labor, 1927–1943.
Committee 16—Economics of Railway Location and Operation, 1930–1945; chairman 1938–1941.
Committee 26—Standardization, 1922–1927; 1938–1941.

He was a diligent member of these committees and an efficient chairman, reconciling differences of opinion among members by his calm and conciliatory manner and his thoroughgoing approach to committee assignments.

Mr. Stout was also a member of New England Railroad Club, the Engineers Club of Minneapolis, and the Minnesota Federation of Engineering Societies. He was active in the religious life of Plymouth Congregational Church, where he was president of adult

bible class, member of Colony Group No. 7, and assistant treasurer. His recreational interests were photography, motoring, tennis, skating and swimming. His personality was quiet and unassuming, with a genial sincerity which endeared him to his associates.

Mr. Stout married Miss Tesse Ellen Waddell of Galveston, Ind., June 11, 1903. He is survived by Mrs. Stout, a brother, Morris Stout, and three sisters, Mrs. Emma Thompson, Miss Minnie Stout and Mrs. Blanche Thorne.

W. B. Irwin, *Chairman,*
H. R. Peterson,
H. H. Edgerton,
Committee on Memoir.

Report on Assignment 1

Revision of Manual

E. E. Kimball (chairman, subcommittee), B. T. Anderson, C. W. Breed, S. B. Clement, G. W. Hand, W. B. Irwin, E. E. King, M. F. Mannion, P. E. Needham, F. N. Nye, J. F. Pringle, E. H. Roth, B. J. Schwendt, L. K. Sillcox, H. W. Snyder, H. P. Weidman.

With the approval of the Board of Direction, Chapter 21 of the Manual has been consolidated with Chapter 16, which thus becomes the Chapter on Economics of Railway Location and Operation, and new sheets 16–71 to 16–90 were issued in the Manual supplement of 1945.

Because your committee noted the need for several minor adjustments in Chapter 21. arrangements were made to incorporate these revisions in the reprinting, and accordingly they are now submitted for formal ratification.

Page 21–1 (Now Page 16–71)

Under the heading, Feasibility and Economy of Through Routing of Solid Trains and Its Effect Upon the Capacity of Terminals, delete paragraph 5 reading, "Supervision of the plant should be centered in a system officer with a knowledge of the requirements of the system and with authority to enforce adherence to the plan." Replace the above paragraph with the following:

"5. The provision of additional classification facilities at principal originating and interchange terminals may obviate the necessity for classifications at intermediate terminals, with a reduction in the over-all cost of terminal operation."

Page 21–12 (Now Page 16–82)

In line 2 of the table in the 4th column after the number 30, insert an asterisk and add the following footnote at the bottom of the table:

"**Note:* Each carrier should use the percent affected by use obtained from tie studies on its own property."

In line 17 of the table in the 4th column insert "10" and in the 5th column insert ".39."

In addition to the above your committee directs attention to the amplifications of an editorial nature.

Page 16–53

Add the words "at 7 miles per hour" to the last sentence of paragraph 2. This sentence then reads, "The locomotive has 47,700 lb. rated tractive effort at 7 miles per hour."

Page 21–9 (Now page 16–79)

The following has been inserted under the title, "(This method has become popularly known as the 'Yager' formula)."

Report on Assignment 3

Methods or Formulas for the Solution of Special Problems Relating to More Economical and Efficient Railway Operation

B. T. Anderson (chairman, subcommittee), J. L. Campbell, S. B. Clement, J. M. Farrin, C. H. R. Howe, W. B. Irwin, Fred Lavis, M. F. Mannion, H. R. Peterson, J. F. Pringle, C. P. Richardson, E. H. Roth, J. A. Schoch, H. F. Schryver, B. J. Schwendt, H. A. Shinkle, H. D. Walker, H. P. Weidman, J. A Wood.

This report is submitted as information with the recommendation that the subject be continued for further study.

Length of Sidings for Freight Train Operation

An increase in the length of sidings has been required by increased train lengths and for improved operating conditions. Formerly, sidings were designed to hold the average freight train of 50 to 80 cars, but with the advent of heavier motive power and modern methods of directing train movements with power operated siding switches, it has been found desirable to adopt longer sidings to provide maximum operating efficiency.

The operation of short trains on 50 to 80 car sidings was generally satisfactory with hand operated switches, but with the adoption of power operated switches in signal indication territory, it became advisable to provide sidings at least as long as the longest freight train and often twice the train length, in order to eliminate delays and expedite traffic. It was found that with the longer sidings and power operated switches a large number of the siding meets were made without stops thus eliminating delays and improving operating performance. It was also found that sidings with power switches could be spaced farther apart to provide a more economical track and signal arrangement.

An important factor with the longer sidings was the adoption of longer turnouts to permit trains to enter and leave at higher speeds, with improved riding of locomotives and decreased turnout maintenance. With the advent of power operated switches and signals to indicate siding occupancy, trains enter sidings at a higher rate of speed. Additional siding length should be provided to permit prompt clearance of the head-in switch and to prevent fouling the main line at the far end of the siding so that opposing or following trains will not be delayed.

By providing long power operated turnouts so that trains can enter and leave sidings at higher speed, time is saved not only in entering and leaving the siding, but in many cases, a train may be advanced one more station than would be possible were it necessary to stop for trainman to handle the switch.

Discussion

Several factors determine the length of siding, as follows:

A. Cars per Train

The number of cars per train may be based on a train of empty cars, a train of loaded and empty cars determined by the tonnage rating of locomotives, the average cars per train, or a standard length of 100, 125, 150 or other fixed number of cars.

B. Average Length of Car

Cars vary in length from 35 to 75 ft. Values of 43, 45, 47 and 50 ft. are being used as an average length.

C. Locomotive

Locomotives vary in length from 90 to 120 ft. for steam and 200 ft. for the 5400-hp. diesel.

D. Caboose

Cabooses vary in length from 35 to 45 ft.

E. Stopping Distance in Siding

Stopping distance is desirable for efficient operation in stopping trains within clearance points. It will vary with local conditions. Some of the factors affecting it are grade, curvature, tonnage or length of trains and speed of train operation. A minimum length may be 300 ft.

F. Slack in Cars

Slack may be included in the length of the car or assumed at 6 in. per car.

G. Track Clearance

Track clearance varies with the size of turnout and track centers, from about 190 ft. for a No. 10 to 375 ft. for a No. 20 turnout.

H. Signal Clearance

Signal clearance depends upon the location of the insulated rail joints and is usually 25 to 50 ft. in the rear of the track clearance point.

I. Highway Crossing Protection

An average of 125 ft. may be used as a minimum.

Formula for Siding Length for Freight Trains

$L = A \times B + C + D + E + F + G + H$, where	*Examples Car Capacity*		
A = Cars per train	100	125	150
	ft.	*ft.*	*ft.*
B = Average length of car	50	50	50
C = Length of locomotive	110	110	110
D = Length of caboose	40	40	40
E = Stopping distance in siding	500	500	500
F = Slack in cars	50	63	75
G = Length of two No. 20 turnouts	750	750	750
H = Length of signal clearance per siding	50	50	50
L = Length of siding between switch points	6500	7763	9025

The examples illustrate the use of the formula. Each railroad should substitute the values applying on a particular project. If more than one locomotive is used per train, if highway crossings are involved or other factors are modified, the formula should be changed accordingly.

Report on Assignment 5

Economics of Railway Location and Operation as Affected by Railway Electrification

Collaborating with Electrical Section, Engineering Division, AAR

L. K. Sillcox (chairman, subcommittee), J. W. Barriger, V. T. Boughton, L. E. Dale, Spencer Danby, C. H. R. Howe, Clark Hungerford, E. E. Kimball, E. E. King, J. M. MacBride, H. J. McKenzie, P. E. Needham, F. N. Nye, E. H. Roth, J. A. Schoch, H. W. Snyder, V. P. Turnburke, H. D. Walker.

The report of your committee this year, which is devoted to the diesel-electric locomotive, is submitted as information.

A locomotive, regardless of type, whether it be reciprocating steam, steam-turbine, electric, or diesel-electric locomotive is no more than a thermal and mechanical unit designed to develop ton miles per hour, with first cost and efficiency of operating performance the basic factors determining its selection. Efficiency of performance means not only availability, reliability, flexibility, tractive effort characteristics, tracking effect, and sustained horsepower, but includes maintenance and operating costs as well. As first cost increases, the importance of availability is intensified, and therefore, because of the greater first cost of the diesel-electric, the design must display a high availability if it is to compete successfully with the more moderately priced conventional type of steam locomotive. It now does this although the efforts of steam locomotive designers and builders are gradually paring the advantage which it presently possesses.

Representative Diesel Performance in Passenger Service

Numerous illustrations might be employed to demonstrate the capacity for utilization of diesel-electric motive power—the characteristic which is so largely accountable for its success and for which steam is not a match. Noteworthy is the record of the "Capitol Limited" handled by the Baltimore & Ohio's 4000-hp. diesel-electric locomotive No. 56, traveling a distance of 771 miles from Washington to Chicago one day, and back the next, never missing a trip for an entire year, and rolling up a total mileage of 281,415. There is the 4000-hp. diesel-electric locomotive No. 1002 of the Atlantic Coast Line, traveling 22,000 miles per month between Florida coast resorts and Washington for a period of four years, without major overhaul. The 2000-hp. diesel-electric locomotive handling the "Peoria Rocket" of the Chicago, Rock Island & Pacific Railway missed only 10 from its 8816 consecutive trips made four times each day over a 161-mile route, at an average speed of 62.3 mph. including stops.

Such illustrations and many others indicate that there are few if any instances in which diesel-electric locomotive records reveal an average availability of less than 90 percent in streamline service. In fact, records of 95 to 100 percent over long periods are the rule rather than the exception. With such availability it is readily understandable why the diesel-electric locomotive has succeeded in attaining unparalleled mileages. The exceptionally high utilization which they provide is partially attributable to their assignment in special service. In many instances these diesels are protected by steam locomotives and are out of service only when necessary because of repair or for operating considerations. Therefore, their utilization is high at the expense of steam power which is standing idle to protect the special services. If a railway were completely dieselized and the diesel power were used for protection as well as routine service, it would be

impossible to utilize all of the locomotives during the 95 percent of the time that they are available. Therefore, while their avilability could remain high, their utilization would be adversely affected.

The manner in which diesel-powered streamlined trains withstood the rigors of war time traffic has enhanced their popularity with railway operating and maintenance officers. The railways found it necessary to lengthen over-all schedules but slightly during the war, and such changes were generally made to conform to ODT orders. Consider for instance the experience of the joint Chicago & North Western–Union Pacific "City of Denver" trains which operate nightly over the 1048 miles between Chicago and Denver. Prior to the war, these trains were operating on a 16-hour schedule westbound, while 15 hours and 40 min. were required to make the trip, Denver to Chicago. At the present time the schedule westbound is 17 hours, while eastbound an hour has been added to the schedule also, making it now 16 hours and 40 min. In other words, the overall operating speeds have been decreased from 65.5 and 66.9 mph. to 61.6 and 62.9 mph. Even at these speeds, and consequent intensive service, these trains as of June 1944, completed 8 years of continuous operation, 7 days per week, without being taken from service, except on two occasions when operating considerations entirely independent of the trains themselves required their removal for short periods. One spare diesel unit has been available for each of the two-unit locomotives for substitution when it was necessary to remove a unit for periodic inspection and repair; all other maintenance has been performed at the two terminals during lay-over hours. During the 8-year period the two trains accumulated the outstanding mileage of 6,084,022, while operating over long distances, averaging speeds of 60 to 70 mph., with a maximum of approximately 100 mph. This is a remarkable achievement and speaks well for the availability and reliability of diesel power.

While the utilization of the diesel locomotive in special services is outstanding, it might be well to add that the mileages obtained in steam locomotive operation are increasing regularly. For example, the J–3 locomotives on the New York Central in 1941 averaged monthly mileages of almost 15,000 per locomotive, and individual monthly mileages of the J–3 and L–4 classes have increased to as much as 24,000. Furthermore, in 1941 the average mileage of the J–3 design between classified repairs was only slightly less than 250,000. This is a utilization which warrants strict consideration.

Maintenance Considerations

Any comparative evaluation of the availability, utilization and performance of the diesel-electric and conventional steam design should include a consideration of the preferred treatment the diesel usually receives in the matter of maintenance, and the fact that initially it was placed in service under most ideal conditions. The diesel was operated at the head-end of streamline, lightweight trains, which gave it every opportunity to display the advantages which it possessed. The reduced train resistance of the lightweight streamline equipment enabled operation at high speeds with markedly reduced operating costs compared to that which would result had standard equipment been utilized. Coincidentally, higher speeds were attainable. Millions of dollars have been spent in the maintenance of diesel locomotives and, being a new motive power type scarcely adaptable to conventional roundhouse maintenance, the diesel has, in many cases, been serviced in modern plants by highly trained and specialized personnel. Because of the seriousness of delay arising from improper maintenance, detailed records have been maintained and the schedule for regular replacement of parts has been respected, even though wear did not indicate that replacement was essential at the time. Contrast this treatment with that given the steam locomotive which in too many cases is indifferently maintained and serviced in obsolete enginehouses with outmoded equipment. Any

comparative analysis of the two power types insofar as availability is concerned should take this difference of maintenance policy into consideration.

Reliability of Diesel Power for High Speed Operations

Reliability, or dependability, is equally important. The extended locomotive runs operated today require reliability of a high order. Weakness in this characteristic would result in very embarrassing and costly interruptions to traffic which cannot be tolerated in the competitive era just ahead. On this point the diesel-electric stands on firm ground since it is unusual for this type to suffer a complete failure, while a steam locomotive failure often means complete stoppage until replacement is secured, or repairs are made. Usually the failure of one unit of a multiple-unit diesel means only a reduction in speed because of the reduced power available.

Further in connection with a comparative evaluation of the availability and performance of the diesel-electric and the steam locomotive of conventional design should be mentioned the fact that during periods of fuel shortage, the steam locomotive has suffered from the effects of unsuitable grades of coal, leading in some cases to engine failure. Apparently the diesel has received a grade of oil which does not have dire effects on its mechanism. The result is that through no fault of its own the steam locomotive sometimes shows up to disadvantage.

Diesel-electric motive power is also utilized for its efficiency in high-speed operation. Illustrative of this feature is the schedule of the Chicago, Burlington & Quincy Railroad's "Twin Cities Zephyr" streamliners—a distance of 427 miles being covered in 6¼ hours with 8 stops en route—an over-all average speed of 68.3 mph. Comparable schedules will probably be realized in the post-war period by many railways which hope to build a future in passenger service for themselves, through programs of track strengthening, realinement and refinement to take advantage of the potentialities inherent in modern motive power units. Such programs may ultimately permit maximum speeds of 100 mph. or even higher. The examples of diesel locomotive performance to the exclusion of reference to the steam locomotive do not imply that only the diesel can operate in these services.

However, inasmuch as the subject assignment relates specifically to the diesel-electric, references to the steam locomotive must be secondary. The Milwaukee's "Hiawatha" service between Chicago and St. Paul embraces both diesel and steam-powered trains thus affording a direct comparison. The excellent performance of the steam locomotives in this service can best be demonstrated by pointing out that the Hiawatha power was designed for a train of six cars to operate at a maximum of 100 mph. However, soon after inauguration of the service the train was lengthened to seven cars, then eight cars, and finally, in an emergency, to ten cars without departing from the schedule. Another example of outstanding steam locomotive performance from the standpoint of speed, regularity, and return on the investment, is the "Daylight Limited" of the Southern Pacific. There are, of course, other notable steam-powered schedules.

Steam vs. Diesel for Heavy Freight and Passenger Service

In the face of the popularity enjoyed by the diesel-electric, and its constantly expanding use, many of the larger systems are conducting investigations designed to improve the efficiency of the steam locomotive, to keep stride with its newer competitor. For instance the Pennsylvania Railroad has built and placed in service a turbine-driven steam locomotive, in addition to its experimental 6–4–4–6, Class S–1, and 4–4–4–4, Class T–1, passenger locomotives. This same system is also responsible for the development of the multi-cylinder 4–6–4–4 type, Class Q–1, designed for high speed, heavy freight service.

Tests, both road and laboratory, of the 4–4–4–4 design have demonstrated that it can handle 16 cars at 100 mph. without drawing upon the full power capacity of the locomotive. It is offered as an alternate to the diesel, and its builders maintain that it will outperform a 5400-hp. diesel at all speeds above 26 mph. With the elimination of service delays en route, it is contended that the steam locomotive of this design can maintain the same schedules as diesel-powered trains. Unfortunately, in too many instances the facilities for servicing a steam locomotive en route are obsolete and its performance suffers. However, this is no basic disadvantage; the deficiency is fully appreciated and there is a tendency to correct the condition.

The Chesapeake & Ohio is planning to build a steam-turbine, electrically-driven locomotive. These roads and others in cooperation with the coal industry are jointly progressing the design of modernized high capacity steam locomotives, to take efficient advantage of the low cost heat energy available in the almost limitless coal reserves. However, certain of these roads are experimenting with both diesel and steam locomotives. For instance, the New York Central, which has long been a protagonist of the steam locomotive and has developed some of the most efficient designs, is now experimenting with the diesel for freight and passenger service in connection with the testing of other types of motive power. Thus it is apparent that the railroads are on the threshold of a period of motive power development. The diesel is driving the steam locomotive to new refinements and even to new forms, but whether these new varieties will cost as much as the diesel, or offer the same degree of reliability, availability, and operating and maintenance costs, is yet to be seen.

The following trends are indicative of the popularity of the diesel-electric locomotive. As of January 1, 1944, Class I Railways had placed orders for 958 locomotives. Of this number, 613 or 64 percent were diesels of various types, while 339, or 35 percent were steam. The remainder were electric locomotives. Deliveries during 1944 amounted to 938 locomotives, 608 being diesels, 329 steam and one electric. At the beginning of 1945, there was even a greater preponderance in favor of the diesel when of 468 orders, 400 or 85 percent were of the diesel-electric type with only 66 steam and two electric locomotives. It should be pointed out that these figures cover locomotives for all services. Therefore, the switching locomotives which are predominantly diesel powered, affect the over-all picture—the disparity with respect to road locomotives being much less.

The Diesel Switching Locomotive

The diesel locomotive has been accepted without question in switching service for several reasons. Most switching operations are performed within the speed range throughout which the diesel displays decided advantage over its steam counterpart, and the high acceleration of which it is capable tends to speed up switching operations. It is also contended, that with the proper gear ratio, a diesel-electric can perform the switching assignments of a steam locomotive having a horsepower rating approximately two and one-half times as much.

In switch service, too, the diesel displays a high availability which can be effectively utilized in many yards. Oftentimes diesel switchers are assigned on a 24-hour basis with provisions for servicing them during lunch periods or at other times when they are not being utilized. Partial explanation for the high availability of the diesel resides in the fact that minor repairs can be made without delay that would be experienced in the case of work on a steam locomotive that would require extinguishing the fire, with an attendant cooling off period, as well as the time consumed in rebuilding the fire and generating the necessary steam pressure. Furthermore, fueling of the diesel is necessary but two or three times per week and can be accomplished in the yard, either from stationary

facilities or from mobile tanks. The steam unit, on the other hand, must go to the roundhouse or other stationary facility for coaling and watering several times a day, and there is the further loss of time for the cleaning of fires. In view of time-consuming operations, the steam locomotive does not average more than 68 percent availability as compared with the generally accepted 95 percent for the diesel switcher.

This would indicate that five diesel units will displace seven steam locomotives in switching service, or a ratio, steam to diesel, of 1.4. This assumes, of course, that the motive power inventory at a specified yard is sufficient to support the ratio. The experience of one railway illustrates this fact, as is noted from the following table:

No. of Steam Locomotives	*No. of Diesel Locomotives*	*Ratio Steam to Diesel*
7	5	*1.40
17	12	1.42
32	23	1.39
8	6	1.33
1	1	1.00

* Calculated—based upon availabilities of 68 and 95 percent for steam and diesel power, respectively.

It will be observed that at one yard 17 steam locomotives were displaced by 12 diesels, or a ratio of 1.42. At another the ratio was 1.39, so that both are very close to the 5 to 7 advantage of the diesel. However, in one yard where but one steam locomotive was assigned, obviously the substitution of a diesel locomotive did not reduce the number of units required. Referring again to the statement that a diesel can perform the assignment of a steam locomotive of 2½ times as much horsepower, diesels of 600-hp. have displaced steam locomotives rated at 1400-hp. With diesel switchers costing $78, and steam locomotives $35, per horsepower, the following capital investment is required on the 5 to 7 basis.

Diesel

Five 600-hp. units at $78 per hp. $= 5 \times 600 \times 78 = \$234{,}000$

Steam

Seven 1400-hp. units at $35 per hp. $= 7 \times 1400 \times 35 = \$343{,}000$

This indicates that the seven steam locomotives would require an investment $109,000 greater than if five diesels were substituted. One advantage of the steam locomotive generally accepted is that its lower first cost reduces the capital investment and incidental fixed charges. However, this is not true in yard operation if sufficient units are required. In any event, it is anticipated that the rate of interest on equipment obligations will continue to decrease, as has been evidenced during the past two years—(the average rate on obligations issued in 1943 was only 2.37 percent). If this trend continues, the difference in investment cost will assume lesser importance relative to the differences in other costs.

Visibility is important in switching operations since quite often signals must be transmitted over relatively long distances and often on curved track, either in the yards or on industrial sidings. The construction of the diesel presents it with an inherent advantage since it has no boiler, tender, or machinery extending to the clearance line. The hood, which houses the engine and generator, is the only obstructive portion of the design, and it is sometimes divided by placing the cab in the center. The cleanliness of the diesel is appreciated both by management and men. Communities are constantly becoming more determined in their demand that smoke be eliminated insofar as feasible.

The diesel does this and has rendered unnecessary the electrification of yards to comply with smoke abatement ordinances. There is no smoke to obstruct the visibility of an engine crew assigned to a diesel switcher, and at the same time the engineman is protected from the elements as well as the radiated heat from a steam locomotive boiler, and incidentally there is the reduction of fire hazard by the elimination of the discharge of hot coals from the fire box and sparks from the exhaust. This enables the diesel to enter certain plants where fire is a hazard without an intervening cut of cars between the locomotive and the cars being switched.

The following pages record a limited amount of comparative cost data on steam and diesel operation for both yard and road service that were submitted by several railways. The actual values vary to such an extent as to restrict their dependability, but they are nevertheless indicative of trends and have some merit for that reason, if for no other. It is the judgment of this committee that extreme caution should be observed in attempting to apply these data to a particular set of operating and motive power conditions because of varied experiences of other systems. All such conditions must be known and compared with those prevailing in the service under examination before any recorded cost data can be intelligently applied. Of course, it is not feasible or necessary for the purposes of this report to detail all factors in each instance which affected final results. To reiterate, the costs included herein are for the purposes of indicating the general trend only.

Economics of Diesel and Steam Power in Yard Service

In the matter of operating costs the diesel is more economical in all accounts except lubrication. It is difficult to compare direct operating expenses as submitted by various railways because of the variance in the manner of bookkeeping. Also it is necessary to consider that in most comparisons relatively new diesel power is related to converted steam locomotives not specifically designed for switching service. For example, the steam locomotives of Road A, were built in 1901 and converted in 1927. They were originally 6-wheel switchers, but when converted their wheel arrangement was expanded to 0–8–0. Their adhesive weight is 108 tons. Those of Road B weigh 133 tons, 103 tons being supported on drivers of a 2–8–2 design. They were built in 1911 and 1912, and have not been converted. The data given to the committee have been developed from costs applicable to diesel locomotives and older forms of steam power, thus making a direct comparison impossible. However, the data on hourly costs are included as of possible interest.

Because lubrication is grouped with water and other supplies in Table 1, the cost differential favoring the steam locomotive in the lubrication account is not evidenced. However, one railway states that the charge to lubrication in the case of its 600-hp. diesels is 4.0 cents per hour as compared with lubricating costs for a steam locomotive of 2.6 cents. This indicates a saving favoring the steam locomotive of 1.4 cents per hour. To the above costs it is necessary to add taxes, insurance, and interest to obtain an over-all comparison. These additional accounts would individually favor the steam because of its lower capital costs. For comparative purposes, experience data of another railway are shown in Table 2.

Table 3, recording the costs of Road D, is applicable to the more modern steam power specifically designed for yard service. The cost data are based upon a lot of 80 locomotives, 65 being built in 1930, 5 in 1942, and 10 in 1943. They are 8-wheel switchers with 25-in. by 28-in. cylinders and 52-in. drivers, weighing from 240,000 to 244,000 lb. Carrying a boiler pressure of 200 lb., they develop cylinder horsepower of 2252. Based upon an original cost of $83,800 per unit and an availability of 75 percent, hourly

TABLE 1.—COST PER HOUR—STEAM AND DIESEL-ELECTRIC SWITCHING LOCOMOTIVES

Road A, 600 and 1000-Hp. Diesels

	Steam	*Diesel*	*Diesel Saving*
Fuel	$1.12	$0.37	$0.75
Water, lubrication and other supplies	0.20	0.08	0.12
Enginehouse expense	0.47	0.04	0.43
Repairs	1.31	0.43	0.88
Wages of enginemen	1.82	1.91	—0.09
Depreciation	0.23	0.55	—0.32
Total	$5.15	$3.38	$1.77

Road B, 1000-Hp. Diesels

Fuel	$1.07	$0.33	$0.74
Water, lubrication and other supplies	0.11	0.03	0.08
Enginehouse expense	0.23	0.04	0.19
Repairs	1.06	0.55	0.51
Wages of enginemen	1.78	1.75	0.03
Depreciation	0.13	0.41	—0.28
Total	$4.38	$3.11	$1.27

TABLE 2.—DATA OBTAINED FROM ROAD C

Unit Costs—Steam vs. Diesel in Yard Service—1944

(600- to 1000-hp. Diesels; 6 and 8-Wheel Steam Switchers)

Account	*Steam 1,253,750 yard-hours cost per yard hour*	*Diesel 306,857 yard-hours cost per yard hour*
Fuel	$ 1.65	$0.39
Water	0.10	...
Lubrication	0.08	0.07
Other supplies	0.05	0.02
Enginehouse	1.22	0.52
Repairs	1.87	0.71
Wages	6.43	5.60
Total	$11.40	$7.31
Total, excluding wages	4.97	1.71
Total for steam wages same as diesel	10.57	7.31
Fuel per hour	927 lb.	6.6 gal.

Note.—In this instance, the saving for the diesel is reflected in lubricants also. This is not in accord with general practice.

TABLE 3.—HOURLY OPERATING COSTS OF 0–8–0 STEAM SWITCHING LOCOMOTIVES—ROAD D

Fuel ($3.25 per ton)	$1.08
Water, lubricants, and other supplies	0.12
Enginehouse expense	0.54
Repairs	1.02
Wages of enginemen	2.17
Depreciation	0.44
Total	$5.37

depreciation is determined to be but $0.44 when a depreciation rate of 3.5 percent is applied. The hourly operating costs of these locomotives, as submitted by the operating railway, are shown in Table 3.

Diesel vs. Steam Motive Power in Freight Service

The latest field of railway operation which the diesel has entered is freight service. As in other services, the diesel can accelerate throughout the low speed range at a higher rate and can handle heavier tonnage because of its higher starting tractive effort and even torque. One railway states that, in comparison, the tonnage rating of steam locomotives on a 1.27 percent ruling grade is 3200, while that of the 5400-horsepower diesel with a 61/16 gear ratio is 3500. If this gear ratio is changed to 62/15 the rating is increased to 3800. The steam locomotives in this instance are of modern design and are considered comparable with the diesel-electric power used in the same service. While it is

Table 4.—Freight Locomotive Operating Data

	Steam	*5400-Hp. Diesel*
Mileage	455,216	216,725
Availability—percent	75	90
Utilization—percent	36	62
Car-miles per train-mile	82.5	89.3
Gross ton-miles per train-mile	3,400	3,801
Gross ton-miles per train-hour	92,303	107,940
Train-miles per hour	27.15	28.39
Average number locomotives in service	10	3
Average cost per locomotive	$174,000	$490,000
Date built	1938	1941

Per Mile Costs	*Steam*	*Diesel*	*Diesel Saving*
Repairs	$0.30	$0.23	$0.07
Depreciation	0.08	0.20	*0.12**
Fuel	0.33	0.28	0.05
Lubricants	0.01	0.05	*0.04*
Water and other supplies	0.05	0.002	0.048
Enginehouse expense	0.04	0.01	0.03
Wages of enginemen	0.18	0.15	0.03
Total cost per locomotive-mile	$0.99	$0.922	$0.068
Total cost per thousand gross ton-miles	$0.2908	$0.2254	$0.0654

* Fgures in italics represent differences favorable to the steam locomotives.

stated that the steam locomotives are believed to be comparable, it should be observed that some authorities contend there is no common ground upon which to compare the performance of the diesel and the steam locomotive. This opinion may be traced to the unrealistic manner in which horsepower ratings are determined. The diesel locomotive is rated according to the horsepower output of the diesel engine, but it can deliver no more than 85 percent of such horsepower at the rails. It would appear that the diesel should be rated at its maximum horsepower at a given speed, or throughout a speed range, as is done in the case of the steam locomotive. As of interest, the tonnage ratings and maximum speeds are shown on the next page as functions of the gear ratio. These values are predicated upon a ruling grade of 2.2 percent when operating without helper service.

Gear Ratio	Tonnage Rating on 2.2 Percent Grade	Maximum Speed on Level Track
59/18	1700	80 mph.
61/16	2000	70 mph.
62/15	2300	65 mph.

The same railway furnishes operating and cost data covering seven months of 1941 which are shown in Table 4. It will be noted that the diesels were new, while the steam locomotives were three years old. This would affect the operating costs.

The diesel locomotive was initially popular on western lines where long distances were traversed with consequent saving in time for servicing en route. Also, the water conditions are relatively poorer in the west, from the standpoint of both supply and quality. The long heavy grades and in some instances the existence of tunnels are further factors favoring the diesel locomotive in the west. In connection with heavy grade operation, it should be mentioned that considerable difficulty has been experienced from the burning out of motors in low-speed, heavy-grade operation. This is a danger, of course, which the steam locomotive does not present.

For comparative purposes it is interesting to note averages provided by a western road* for a year's operation:

	Steam	Diesel
Gross ton-miles per train-hour	29,747	52,985
Gross ton-miles per locomotive-mile	1,624	2,998
Train-miles per train-hour	13.55	17.67
Repair cost per mile	$0.44	$0.23
Power type—articulated		5400-hp.

No age figures are given, although the indications are that the steam locomotives are not of the most modern design. For example, in contrast with the $0.44 per locomotive-mile for repair costs given above, a railway operating with modern articulated freight units, roller bearing equipped, reported a repair cost of $0.237* per mile. In comparison, the Norfolk & Western** reports that its unit repair costs for the 2–6–6–4, Class A, design is $0.21, while that for its 4–8–4, Class J, locomotives is but $0.115 per mile.

Another system* operating in the mountainous territory of the west has furnished the following operating data:

	Steam	Diesel
Miles operated	700,000	400,000
Percent total time in service	32	59
Percent at shop or terminals	46	11
Percent available but not being used	22	30
Gross tons per train	2,610	3,325
Total operating cost per mile	$1.70	$0.82
Repair cost per mile	0.74	0.20
Fuel cost per mile	0.58	0.34

Effect of Age on Diesel Repair Costs

In a preceding paragraph it was pointed out that the diesels involved were new, and to indicate the manner in which repair costs vary with age, Table 5 is included: (No doubt a portion of the increase is attributable to increased labor rates and material costs and inefficiency of inexperienced labor necessarily employed during wartime.)

* Railway Age, May 19, 1945, p. 888.
** Railway Age, June 2, 1945, p. 971.

It will be noted that maintenance costs on new diesels are very low and tend to rise rather rapidly in early years of service. Adequate records are not presently available to indicate when a period of stability is reached, nor are the records of one road necessarily comparable with those on another, because of the age factor, wage levels, shop facilities, number of locomotives being serviced, etc. Furthermore, when special facilities are required for the maintenance and servicing of diesel locomotives, that cost should be included in any comparative figures. On the other hand, as a railway increases its use of diesel power, the need for steam power facilities decreases, offsetting, to a degree dependent upon local conditions, the diesel facilities expense.

TABLE 5.—RELATION OF UNIT REPAIR COSTS TO DIESEL LOCOMOTIVE AGE

	Repair Cost—Cents	
	Per gal. oil	*Per 1000 gtm.*
Freight		
1941—First year	3.48	7.97
1942—Second year	5.56	11.63
1943—Third year	7.79	15.48
1944—Fourth year	10.29	20.80
Percent increase:		
1944 vs. 1941	195.69	160.98
	Per gal. oil	*Per Passenger car-mile*
Passenger		
1941—First year	4.11	1.05
1942—Second year	5.51	1.56
1943—Third year	9.30	2.72
1944—Fourth year	13.05	3.75
Percent increase:		
1944 vs. 1941	217.52	257.14
	Per gal. of oil	*Per yard-hour*
Switch		
1941—First year	4.34	29.04
1942—Second year	6.21	39.82
1943—Third year	9.44	60.94
1944—Fourth year	10.85	71.15
Percent increase:		
1944 vs. 1941	150.00	145.01
	Per gal. of oil	
Total		
1941—First year	4.04	
1942—Second year	5.65	
1943—Third year	8.86	
1944—Fourth year	11.65	
Percent increase:		
1944 vs. 1941	188.37	

Also in connection with diesel repair costs, consideration should be given to the possibility that the values shown do not reflect actual cost. This statement is based upon the understanding that in some instances, with the introduction of the diesel, the builders of the locomotive have guaranteed a maximum maintenance figure. Should it happen that this value was exceeded, the manufacturer agreed to absorb the extra costs. While this may not have been the situation generally, it possibly should not be overlooked.

In this same connection, the fact that diesels are standardized has operated to their advantage in repair cost when compared with that necessary to maintain the steam counterpart in service.

This standardization has enabled the railways to maintain supplies of standard parts at strategic points thereby permitting prompt replacement at a minimum cost, and incidentally increasing the unit's availability and utilization. On the other hand, the railways insist upon individual design of their steam locomotives which means such a multiplicity of parts that the maintenance of supplies at numerous points is not feasible. This is no inherent weakness of the steam locomotive, and it is unfortunate that its performance and maintenance cost records must suffer through no fault of this type of power.

It is evident that fuel costs are undergoing considerable change and may do so for some time to come, as indicated by the bituminous coal wage increases for instance. While there have been increases in the cost of diesel fuel, the effect per service unit is not as significant as in the case of coal. To illustrate, the following figures are quoted: the cost of locomotive coal was $2.45 per ton in 1940 and $3.33 in 1944; in the same years locomotive coal cost 96 cents per yd. switching-hour as compared with $1.37—an increase in excess of 42 percent with a further increase due in 1945. The increase in the cost of diesel fuel per yard switching-hour in the same period was from 28 cents to 32 cents, or less than 15 percent. These figures indicate the importance of the study of relative trends in cost of fuels utilized—and the long term availability of solid vs. liquid fuels.

In comparing labor costs, often there are extra expenses incurred in cases where it is found desirable to have a maintainer ride the diesels continuously.

Estimated Diesel Savings—All Services

Concluding the matter of costs, one railway has submitted the figures for over-all saving for 1944 shown in Table 6.

Table 6.—Estimated Diesel Savings

1944

Service	*Operating Savings*	*Percent as Compared to Steam Operation*	*Investment*
Freight	$1,223,999	44.6	$4,000,000
Passenger	820,725	26.3	2,945,000
Switch	1,002,226	30.8	2,866,750
Total	$3,046,950	33.5	$9,811,750

Service	*Percent Return on Investment*	*Equivalent No. Steam Locomotives*	*Number Diesels In Service*
Freight	30.6	30	8, 5400 hp.
Passenger	27.9	40	7, 4000 hp.
Switch	35.0	72	3, 2000 hp. 39, 600–1000 hp.
Total	31.1	142	

Thirty-nine diesel switching locomotives replacing 72 steam units is a surprisingly high ratio and is not in accord with the experience of another system as reported on page 58. However, the figures are reported as submitted, with the repeated statement that comparative costs are predicated on limited data.

Summary of Factors Governing Motive Power Selection

The data in Table 6 may suggest that dieselization is indicated in the interest of economy. This is not true since if the service to which the power is to be assigned cannot support high utilization, then the economies of diesel operation cannot be realized because of the high first cost. Based upon 1944 costs, the 5400-hp. freight diesel cost approximately $496,000, while the 6000-hp. passenger design exceeded this cost by $26,000. Contrast these values with that of the 4–8–4 steam locomotive which in the same year cost $225,000, and it is immediately apparent that high utilization must be obtained if the elevated first cost of the diesel is to be defended.

Complete familiarity with the main characteristics of the three types of motive power—electric, steam, and diesel-electric—is a prime essential in selecting either the type or combination of types best adapted to a particular situation. In summary, rated under five main classifications, the following results are noted:

Regarding operating costs, the electric locomotive is at a disadvantage in fuel costs, the diesel-electric in lubrication costs, while the steam is at a disadvantage in fuel, water, enginehouse expenses, and repair costs, the exception being lubrication.

With reference to fixed charges, a decided superiority is realized by the steam locomotive in each of the three items of: First cost; depreciation; and interest, taxes and insurance. The electric shows advantage in depreciation costs, while the diesel-electric enjoys no advantage at all, except in yard service when diesel switchers can displace steam power on a 5 to 7 basis as noted on page 58.

With regard to operating characteristics, the steam locomotive is at a disadvantage in each of the six considerations of overload capacity, high acceleration, availability, flexibility, use factor, and freedom from complete breakdown; the electric shows an advantage in all but the last two mentioned, and the diesel-electric in all but the first mentioned.

In consideration of special features, the steam locomotive is again at a disadvantage, while both the electric and the diesel-electric enjoy superiority in smoke elimination, damage to roadbed, merchandising appeal, and dynamic braking.

Finally, in respect to the possibility of eliminating facilities relative to operating and maintenance, the steam locomotive rates no advantage while the electric and diesel-electric enjoy superiority in both of these possibilities. An offset to this, however, is the fact that economical maintenance of any substantial number of electric or diesel-electric locomotives requires specialized shops entailing substantial capital expenditures in addition to those made for the locomotives.

Report of Committee 9—Highways

A. P. Button, *Chairman*,
C. J. Astrue
W. E. Axcell
F. D. Batchellor
H. D. Blake
H. E. Brink
H. F. Brockett
H. C. Charlton
A. R. Dewees
C. F. Edwards*
P. W. Elmore
H. L. Engelhardt
A. S. Haigh
W. J. Hedley
Warren Henry
C. D. Horton
T. J. Jaynes
J. A. Johnson
Maro Johnson
R. B. Kittredge
A. E. Korsell
G. P. Palmer
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T. M. Pittman
L. J. Riegler
L. S. Rose
H. M. Shepard
F. A. Stone
R. R. Strother
W. C. Swartout
E. G. Wall
V. R. Walling
R. E. Warden
Committee

* Died June 1, 1945.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions..... page 68

2. Design and specifications for highway crossings at grade over railway tracks, both steam and electric, collaborating with Committee 1, and with American Society of Municipal Engineers, and American Transit Association.

   Progress report, specifications for the construction of prefabricated sectional treated timber crossings, recommended for inclusion in Manual..... page 69

3. Comparative merits of various types of grade crossing protection, collaborating with Signal Section, AAR, and Highway Research Board.

   Progress report, presented as information..... page 71

4. Requisites for location, number and arrangement of automatic signals, automatic gates and auxiliary signs for rail-highway grade crossing protection, collaborating with Signal Section, AAR, and AAR Joint Committee on Grade Crossing Protection.

   No report.

5. Method of classifying grade crossings with respect to public safety.

   No report.

6. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

   No report.

The Committee on Highways,
A. P. Button, *Chairman*.

AREA Bulletin 455, November 1945.

Report on Assignment 1

Revision of Manual

A. S. Haigh (chairman, subcommittee), Bernard Blum, C. J. Astrue, H. E. Brink, H. F. Brockett, P. W. Elmore, C. D. Horton, Maro Johnson, R. B. Kittredge, A. E. Korsell, G. P. Palmer, W. C. Pinschmidt, T. M. Pittman, L. J. Riegler, L. S. Rose, V. R. Walling.

Your committee recommends that the following changes be made in the manual:

Specification for Highway Grade Crossings and Approaches Other Than Those for Which Requirements are Stipulated by Law

It is recommended that paragraph 3 on page 9–1, as well as Fig. 918 on page 9–2 be deleted. This paragraph reads as follows:

"When a highway crosses a railroad at an angle less than a right angle, consideration should be given to changing the alinement of the highway, so that the portion within the limits of the railroad right-of-way will be at right angles to the track. (Fig. 918)."

Figure 903–A.—Mounting for Highway Crossing Sign, 50-Deg. Reflector Type.

It is recommended that Note 1 in regard to location be eliminated, as the signs should be located as required by local conditions to admit of the best view by persons approaching the crossing.

That in Note 4, the word "reflectorized" should be "reflector".

That the notes be renumbered.

That the dimension be changed so that top of footing will be shown as 6 in. above the crown of the highway.

Figure 904.—Highway Crossing Signal Assembly, Wig-Wag Type.
Figure 905.—Highway Crossing Signal Assembly, Wig-Wag Type.
Figure 906.—Highway Crossing Signal Assembly, Flashing Light Type.
Figure 907.—Highway Crossing Signal Assembly, Flashing Light Type.
Figure 907–B.—Highway Crossing Flashing Light Signal Assembly, Cantilever Type.
Figure 907–A.—Highway Crossing Flashing Light Signal Assembly, Cantilever Type.
Figure 931–A.—Automatic Crossing Gate and Signal Assembly.

It is recommended that dimension of these plans be changed so that the top of the footing will be shown as 6 in. above the crown of the highway.

Report on Assignment 2

Design and Specifications for Highway Crossings at Grade over Railway Tracks, both Steam and Electric

Collaborating with Committee 1, and with American Society of Municipal Engineers, and American Transit Association

W. J. Hedley (chairman, subcommittee), W. E. Axcell, F. D. Batchellor, H. D. Blake, H. F. Brockett, A. R. Dewees, P. W. Elmore, A. S. Haigh, C. D. Horton, A. E. Korsell, A. E. Perlman, F. A. Stone, W. C. Swartout, E. G. Wall, V. R. Walling, R. E. Warden.

Your committee submits the following progress report with the recommendation that it be adopted for publication.

SPECIFICATIONS FOR THE CONSTRUCTION OF PREFABRICATED SECTIONAL TREATED TIMBER CROSSINGS

1. General

These specifications cover the fabrication and installation of sectional treated timber crossing for highway with railroad track. The completed crossing shall consist of prefabricated sections, which may be removed and reinstalled individually. These specifications shall be carried out in detail and with first class workmanship.

2. Track Structure and Size of Crossing

The track structure shall be designed and constructed in accordance with AREA specifications. New sawed ties should be inserted throughout the crossing area. The length of the crossing, measured along the track, shall be sufficient to provide a roadway over the track at least as wide as the pavement and the usable roadway immediately adjacent.

3. Materials

Crossing sections shall be made of timber, preferably of one of the following, stated in order of preference: (1) Black gum; (2) tupelo gum; (3) sweet gum. If shims are used they shall be of the same material.

4. Size of Sections

(a) *Length.*—The sections shall be made in lengths which are multiples of the tie spacing used in the track. An 8-ft. length is recommended.

(b) *Width.*—The center sections of the crossing shall be of such width that two of them will make up that portion between the running rails, allowing sufficient flangeway opening. A width of 25½ in. is recommended for each center section. Outside of the rail one section shall fit against the head of the rail and shall be of such width as to extend to the end of the ties, but shall not overhang the end of a tie of nominal length by more than 3 in. Sections for use in the intertrack space shall have a minimum width of 20 in. In determining the width of intertrack sections, allowance should be made for a ½-in. space between sections.

(c) *Depth.*—Crossings may be of either of two types.

Type A crossings shall be full depth. The depth of the sections shall be such that the top surface of the crossing will lie in the plane of the tops of the rails with the

bottom of the section resting directly on the cross ties. In determining this depth, allowance should be made for the depth of the tie plate and for the nominal depth of adzing of the ties.

Type B crossings are made with shims or furring strips between the bottom of the sections and the top of the ties. The combined depth of the sections and shims shall be such that the top surface of the crossing will lie in the plane of the tops of the rails. Proper allowance should be made for the depth of tie plate and for the nominal depth of adzing of the ties. Sections shall have a minimum depth of 5⅞ in. Shims shall have a minimum thickness of 1⅝ in. and shall be made of material having a nominal width of 8 in.

5. Fabrication

The sections shall be made true to plan measurements in all three dimensions. The underside of one edge of the sections of Type A crossings and the ends of the shims of Type B crossings shall be shaped to allow for necessary clearance over tie plates and spike heads. The upper corner of the timber adjacent to the flangeway opening shall be given a ½-in. bevel. The top surface of the timber which fits against the rail head on the outside shall be planed down a depth of ¼ in. below the top surface of the crossing for a distance of 3 in. from the edge of the timber. The ends of all sections shall be squared off. The outside ends of the end sections shall be beveled, the bevel having dimensions of 8 in. horizontally and 4 in. vertically. Each section shall have at least 4 holes for use in anchoring the section to the ties with lag screws. These holes shall be $\frac{13}{16}$ in. in diameter and shall have a 2⅝-in. counter bore 1¼ in. deep in the top side. Each shim shall have two ¼-in. diameter holes for use in fastening it to the tie.

All timbers shall be so placed that when the section is in its normal position in the track, the heartwood of the timber will be on the bottom side. Timbers which are relatively thin shall be placed on the inside of the section. No timber having a dimension of less than 2 in. shall be used. The individual timbers of each section shall be permanently held together with a minimum of three steel bolts or twisted dowels, not less than ¾ in. in diameter, placed horizontally through the timbers, either at the center of their vertical dimension or staggered not more than 1 in. off center in each direction. Toothed-ring timber connectors may be used between the individual timbers of the section. All fabrication of the individual timbers and shims shall be completed prior to treatment.

6. Flangeways and Fillers

An opening not less than 2½ in. wide and 2 in. deep shall be provided for the flangeway on the gage side of the running rails. The width of the flangeway opening shall not exceed 3 in. Flangeway filler blocks of treated timber shall be placed below the head of the rail on the gage side between the web of the rail and the edge of the crossing section. The filler block shall be of such size and shape as to provide a snug fit.

7. Treatment

All timber shall be treated with preservative in accordance with the AREA Specifications for the Preservative Treatment of Wood.

8. Installation

Before the crossing sections are put in place, ties shall be accurately spaced so that when in place the ends of each section will be at the center of a tie. The shims of a Type B crossing shall be secured in place with 60-d spikes. After the sections have been properly located, holes shall be bored in the ties, and through the shims in Type B cross-

ings, to receive the lag screws. In ties of oak or similar hardwoods these holes shall be $\frac{9}{16}$ in. diameter; in ties of pine, fir or similar woods, they shall be $\frac{13}{32}$ in. diameter. Holes shall be filled with creosote oil before the lag screws are placed. Each section shall be anchored in place with four $\frac{3}{4}$ in. diameter lag screws. In track where the rail is of 110-lb. section or lighter, the lag screws shall be 10 in. long. In track of heavier rail, lag screws shall be 12 in. long. Lag screws shall be screwed in place—not driven. After the lag screw is in place, the space in the counter bore may be filled with a mastic material if the installation is made at a location where such treatment seems desirable.

9. Relation of Crossing to Adjacent Pavement

The elevation of the top surface of the crossing shall be the same as the highway pavement immediately adjacent. A 1-in. expansion joint shall be provided between the crossing and the pavement.

Report on Assignment 3

Comparative Merits of Various Types of Grade Crossing Protection

Collaborating with Signal Section, AAR, and Highway Research Board

G. P. Palmer (chairman, subcommittee), Bernard Blum, W. E. Axcell, F. D. Batchellor, H. D. Blake, H. E. Brink, A. R. Dewees, H. L. Engelhardt, Warren Henry, T. J. Jaynes, Maro Johnson, R. B. Kittredge, W. C. Pinschmidt, F. A. Stone, R. R. Strother, E. G. Wall, R. E. Warden.

Your committee submits the following progress report as information:

The work this year has again been limited to a continuation of tests of reflectorized signs other than button signs.

Scotchlite Reflector.—This is a powdered glass on a fabric base cemented to wood or metal crossbuck signs.

Signs installed at Central Avenue, Chicago, December 10, 1940, appear to be in as good condition as reported last year.

Signs installed at 109th Street, Chicago, on April 14, 1941, are about the same as reported last year.

The signs installed in November, 1941, at Stearns Road, Chestnut Ridge Road and Maddock Road in the vicinity of Olmsted Falls and Shawville, Ohio, will stand out fairly well at night, but the lettering cannot be read at any great distance. The fabric is starting to peel off at the ends of the arms and at the top of the auxiliary "4 Track" signs on all the signs facing south where they are exposed to the sun. This condition has been reported heretofore on similar signs in the Chicago area.

Signs installed at Steele Road and Ingalls Road near Joliet, Ill., in November 1941, appear to be as good as when first installed.

The sign installed in November 1941, at Marion Road, Columbus, Ohio, appears to be in the same condition as reported a year ago. Due to considerable dirt and smoke the sign is not giving desired results.

The signs at State Route 199, south of Moline, Ohio, which were installed in July 1943, are still in good condition the same as reported last year.

Alzak Signs.—These are metal letters using Arbuckle reflecting metal. The sign on test at 104th Street Chicago installed March 3, 1941, is still in fairly good condition.

Cuneo Sign.—This is a decalcomania process. A sign was installed at Lawndale Avenue, Chicago on the Indiana Harbor Belt Railroad facing north, on April 5, 1943. This sign appears to have faded and does not give a very clear indication.

Mirolite Sign.—This sign was installed at Lawndale Avenue, Chicago, facing south, on January 7, 1944. The letters are of special glass with beaded face and smooth back, on which the lettering is painted in white with a black background. This is attached to a Masonite board with special mastic and edge encased in metal molding. This sign shows additional failure during the past year. Two sections of the glass are now broken and two additional letters are cracked. The background is faded so that the lettering is not visible at a distance.

Conclusion

The tests of some of the reflecting materials reported here have progressed to such an extent that the subcommittee feels it can recommend the use of such material where the expense of reflector button signs is not justified, and where flashlights, gates or street lights are not in service.

Report of Committee 13—Water Service, Fire Protection and Sanitation

B. W. DeGeer, *Chairman,*
R. C. Bardwell
W. M. Barr
C. W. Brown, Jr.
I. C. Brown
R. W. Chorley
R. E. Coughlan
J. H. Davidson
J. J. Dwyer
C. H. Edwards
C. E. Fisher
R. N. Foster
R. H. George
F. L. Guy
S. H. Hailey
J. P. Hanley
E. C. Harris
T. W. Hislop, Jr.
A. W. Johnson
H. F. King
C. R. Knowles
W. B. Leaf
G. A. Little
O. E. Mace
G. E. Martin
Ray McBrian
W. A. McGee
H. L. McMullin
G. F. Metzdorf
R. H. Miller
E. R. Morris
Theodore Morris
M. F. Neuzil
E. M. Grime, *Vice-Chairman*
A. B. Pierce
S. E. Printz
W. A. Radspinner
H. M. Schudlich
R. W. Seniff
J. M. Short
H. E. Silcox
R. M. Stimmel
T. A. Tennyson, Jr.
J. E. Tiedt
E. R. Trodd
C. P. Van Gundy
H. W. Van Hovenberg
R. E. Wachter
K. J. Weir
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, embracing revisions of water service terms in the Glossary.. page 74

   Progress report including revision of Specifications for Timber Substructures for Wood Water Tanks and revised drawing submitted for adoption..... page 76

2. Cause of and remedy for pitting and corrosion of locomotive boiler tubes and sheets, with special reference to status of embrittlement investigations.

   Progress report, presented as information..... page 79

3. Progress being made by federal or state authorities on regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR.

   Progress report, presented as information..... page 79

4. The principal current activities of the Fire Protection and Insurance Section, AAR.

   No report.

5. Mechanics of foaming and carryover in locomotive boilers.

   No report.

6. Methods for taking water samples.

   Final report, presented as information..... page 83

7. New developments in lime-soda ash water treating plants and equipment.

   No report.

8. Economics of silica removed from boiler feedwater.

No report.

9. Methods of removing oily deposits from inside of locomotive boilers.

Final report, presented as information..... page 85

10. Means of conserving labor and material including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools, and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

Final report..... page 87

THE COMMITTEE ON WATER SERVICE, FIRE PROTECTION AND SANITATION,
B. W. DEGEER, *Chairman.*

Report on Assignment 1

Revision of Manual

E. M. Grime (chairman, subcommittee), C. W. Brown, Jr., I. C. Brown, R. E. Coughlan, R. H. George, T. W. Hislop, Jr., A. W. Johnson, H. F. King, C. R. Knowles, W. B. Leaf, G. A. Little, G. E. Martin, H. L. McMullin, G. F. Metzdorf, R. H. Miller, Theodore Morris, H. E. Silcox, T. A. Tennyson, Jr., R. E. Wachter, K. J. Weir.

Your committee submits the following revision of Section 603.—Indicator, appearing on page 13–38.5 in the Specifications for Welded Steel Tanks for Railway Water Service.

Present form: "An indicator shall be furnished and installed for the full height of the tank complete with a suitable float, target and bronze metal sash chain."

Proposed form:

An indicator shall be furnished and installed for the full height of the tank, of 10-inch channel iron complete with suitable metal float, target with guides, and bronze metal sash chain.

Your committee has also given consideration to the water service terms now in the Manual Glossary with the object of revising them where desirable, adding such new terms as are required by developments in the art, and eliminating all words or terms which are ordinarily found in dictionaries or reference books available to water engineers.

Accordingly, the following revised and abridged list of terms relating to water service are submitted for adoption and publication in the Glossary in place of terms relating to water service now appearing therein.

Glossary of Terms Relating to Water Service

AIR CHAMBER.—A closed chamber used on the discharge or suction side of a pump to promote a uniform flow of water and to equalize stresses upon the pump and the piping.

ALKALI WATER.—A term commonly used to designate water containing in solution any compound of sodium or potassium in appreciable amount.

AQUAGLOBEJECTION.—The contamination of steam by droplets of boiler water hurled into the steam space by violent bursting of steam bubbles at the liquid surface.

Blowdown.—The act of letting water out of a boiler under pressure for the purpose of reducing the concentration of dissolved and/or suspended solids.

Continuous Plant (Water Treatment).—A plant so designed that the untreated water may be pumped through it without interruption and where the volume of the chambers through which it passes before flowing to storage is sufficient for complete reaction and precipitation.

Carryover.—A contamination of steam discharged from a boiler, by boiler water or its impurities.

—(a) Foaming.—A type of carryover resulting from the formation of foam (froth) on the surface of the boiler water to the extent that it is carried over with the steam leaving the boiler.

—(b) Foam Spray.—Contamination of steam consisting of fragments of bursted foam bubbles.

—(c) Priming.—The projection of slugs of water into the steam space caused by sudden heavy demand for steam.

Deionization.—The removal of positive and negative ions by passing water through two beds of organic sand.

Foaming.—A type of carryover resulting from the formation of foam (froth) on the surface of the boiler water to the extent that it is carried over with the steam leaving the boiler.

Foam Spray.—Contamination of steam consisting of fragments of bursted foam bubbles.

Grooving.—Localized corrosion of boiler steel in overstressed areas, resulting in well defined channels.

Hardness (Water).—The quality of water due to incrusting solids held in solution.

Hardness (Pseudo).—That caused by sodium chloride, free mineral acid and sodium sulfate in high concentrations.

Intermittent Water Treating Plant.—A plant so designed that the water is pumped alternately into two or more treating tanks, chemicals added and there retained until chemical reactions and precipitations are completed.

Pipe, Blowoff Branch.—A pipe fitting, usually in the form of a tee, with an opening at an angle with the main pipe end designed to form a connection for a blowoff valve.

—Drop.—The vertical line of pipe through which the water is discharged from a well.

—Service.—A line through which water is distributed to points of actual use as distinguished from suction lines and discharge lines to tanks or reservoirs.

Pipe Offset.—A casting in the form of a reverse curve designed for the continuation of a line of pipe in a line parallel to its beginning.

Pitting.—Localized corrosion.

Power Head.—A machine placed over a well connected to the power unit and which, by means of the pump rods, operates the piston in the working barrel.

Priming.—The projection of slugs of water into the steam space caused by sudden heavy demand for steam.

Pump, Moyno.—A positive endwise displacement pump of a rotary type consisting of a stator with an internal form of a double helix in which is operated a rotor consisting of a single helix. Since the rotor is in continuous contact with the stator throughout its entire length, the pump is valveless and self-priming.

Standpipe.—A tank in which the bottom is located at or near the surface of the ground, the interior of the entire structure being utilized for the storage of water.

Suspended Matter.—Undissolved particles of matter in water which may be removed by filtration and/or sedimentation.

Track Pan.—A shallow trough located between the rails, from which water is taken by locomotives while in motion by means of a scoop located under the tender.

Valve, Air Relief.—A device for releasing entrapped air without releasing liquid.

Water Column.—A mechanical device consisting of valve, vertical pipe and spout, through which water is controlled and delivered to a locomotive tender.

Well, Artesian.—A well in which the water level is raised above the normal ground water level by subterranean pressure.

—Flowing.—An artesian well in which the water rises above the surface on the ground.

—Gravel Wall.—A well having a screen with openings larger than ordinarily used and having selected gravel applied around the screen, and casing immediately above the screen, to prevent extremely fine sand from entering the well.

Supplemental Report of Assignment 1

Revision of Manual

Revised Specifications for Timber Substructures for Water Tanks

H. E. Silcox (chairman, special subcommittee), R. E. Coughlan, J. H. Davidson, T. W. Hislop, Jr., A. W. Johnson, H. F. King, G. E. Martin, A. B. Pierce, J. E. Tiedt, R. E. Wachter, K. J Weir

Your committee submits revised Specifications for Timber Substructures for Water Tanks, 50,000 and 100,000 Gal. Capacity, and a plan for timber substructures for water tanks of 50,000 gal. (16 ft. by 24 ft.) and 100,000 gal. (20 ft. by 30 ft.) capacity, with the recommendation that the specifications and the plan be approved for publication in the Manual to replace the specifications shown on page 13–29 and the plans shown as Figs. 1306 and 1307 on pages 13–30 and 13–31, respectively.

SPECIFICATIONS FOR TIMBER SUBSTRUCTURES FOR WATER TANKS

50,000 and 100,000 Gal. Capacity

1. General

The structure will consist of a 12-post timber tank tower complete in all details, as shown on the plan, for supporting a wood water tank of the specified size and capacity at the required elevation. The intent of the plans and specifications is to include all material required between the bottom of the foundation and the bottom of the tank.

2. Materials, Design and Workmanship

(a) Piles shall meet the requirements of AREA Specifications for Wood Piles.

(b) Structural timbers shall meet the requirements of AREA Specifications for Structural Timbers.

(c) The structure shall be designed in accordance with AREA Specifications for Design of Wood Bridges and Trestles for Railway Loading.

(d) Where treated timber is used, the preservatives shall meet the requirements of AREA Specifications for Preservatives.

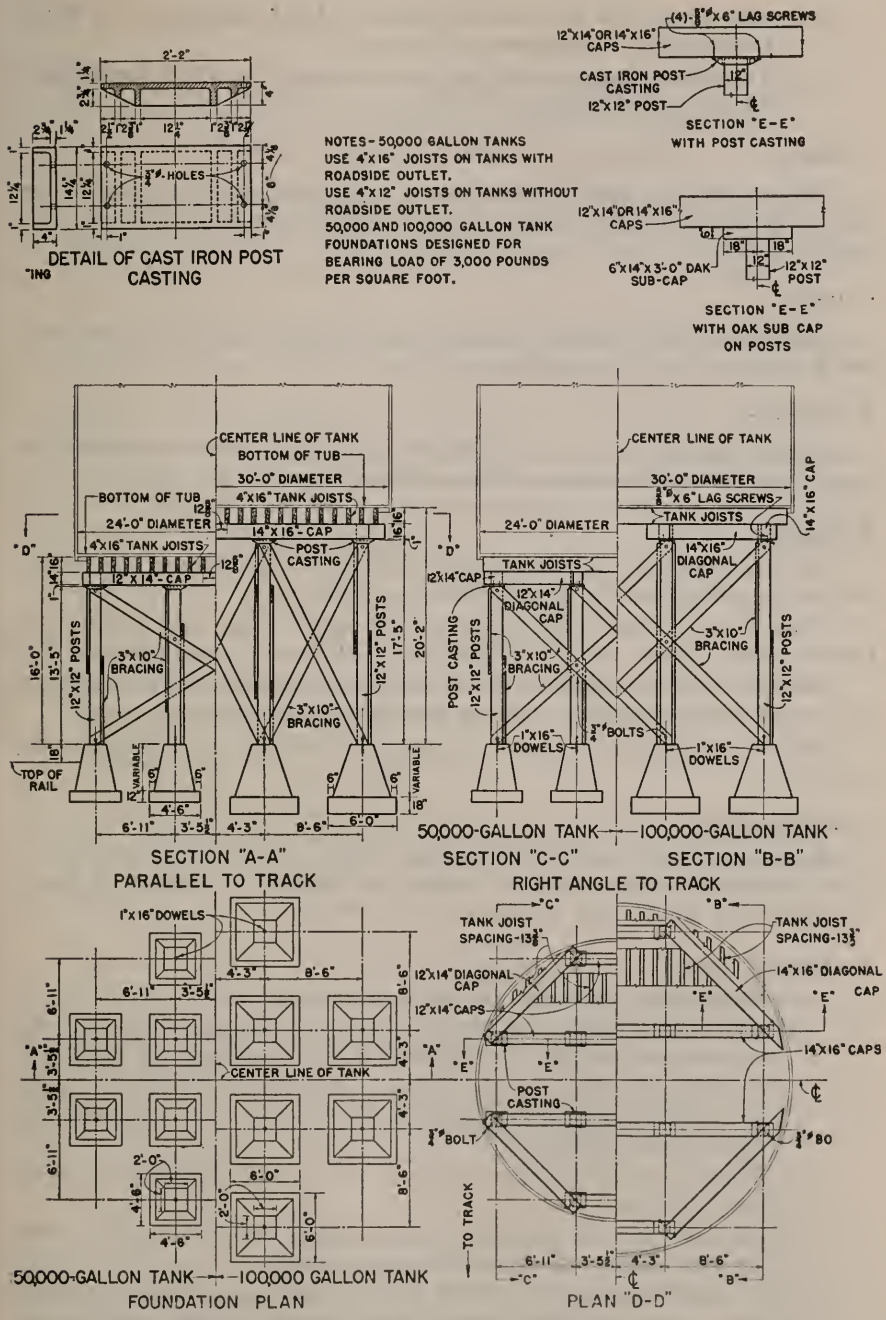

Fig. 1306.—Twelve-Post Timber Water Tank Tower for 16-Ft. by 24-Ft. and 20-Ft. by 30-Ft. Tanks.

(e) Metal details shall meet the requirements of AREA Specifications for Metal Details used in Wood Bridges and Trestles.

(f) The concrete pedestals shall meet the requirements of AREA Specifications for Concrete and Reinforced Concrete.

3. Timber

The type and stress grade of timber, treated or untreated, shall be specified by the engineer, the timber to be S4S and shall conform to the specifications noted in (b), (c) and (d), Article 2.

4. Metal

The kinds of metal and their dimensional details shall be designated by the engineer in accordance with the specification noted in (e), Article 2.

5. Concrete

Concrete pedestals, of the spread footing type or on timber piles as specified by the engineer, shall meet the requirements of the specifications noted in (f), Article 2.

6. Painting

The ends of all posts and all contacts of timber with wood, concrete, steel or cast iron shall be painted with hot creosoted oil before erection.

Untreated timber shall receive one primer and one finish coat after framing, and exposed surfaces of timber in the assembled tower shall receive a second finish coat.

Metal shall receive one primer and one finish coat before being placed in position, and exposed surfaces shall receive a second finish coat after the tower is assembled.

The type and color of the paint or preservative shall be as designated by the engineer.

7. Workmanship

Workmanship shall conform with the best current practice, and with Article 3, (b to e, inclusive); Article 4, (b to e, inclusive) and Articles 5, 6, 7 and 8, of AREA Specifications for Workmanship for Pile and Frame Trestles.

8. Drawing Notes

(a) All bolts shall be installed with cast washers on each end.

(b) All drift bolts shall be ¾ in. diameter and of the proper length required by the cap dimensions, allowing for a minimum of 8 in. penetration into the posts.

(c) In event oak subcaps are used in place of cast iron post castings, the subcap shall be anchored to the cap and post by means of lag screws or scabs on the sides of the post and cap.

(d) Bridging between tank joists shall be of 1-in. by 3-in. material on the center line of the caps.

(e) The length of posts when used with oak subcaps shall be 5 in. shorter than the length shown with the cast iron post castings.

(f) In event the tank is to be fitted with a roadside outlet, the joists shall be 4 in. by 16 in. to provide clearance between the top of the cap and the bottom of the tub for the outlet pipe and elbow.

Report on Assignment 2

Cause of and Remedy for Pitting and Corrosion of Locomotive Boiler Tubes and Sheets, with Special Reference to Status of Embrittlement Investigations

R. E. Coughlan (chairman, subcommittee), R. C. Bardwell, W. M. Barr, R. W. Chorley, J. H. Davidson, C. H. Edwards, E. M. Crime, T. W. Hislop, Jr., H. F. King, C. R. Knowles, Ray McBrian, W. A. McGee, R. H. Miller, Theodore Morris, A. B. Pierce, S. E. Printz, R. W. Seniff, R. M. Stimmel, J. E. Tiedt, C. P. Van Cundy.

This is a progress report presented as information.

During the past year your committee has been unable to report more than progress in the further development of preventives to intercrystalline corrosion.

The use of organic inhibitors and also sodium nitrate confirm the previous reports on preventives for this particular type of corrosion.

During the past year considerable progress has been reported in the development of the welded boiler and it is the hope of this committee that during 1946 several locomotives with welded boilers will be in service on different railroad systems. The performance of these locomotives will be followed carefully in order to report fully on this method of construction as a preventive of intercrystalline corrosion at a later date.

Report on Assignment 3

Progress Being Made by Federal or State Authorities on Regulations Pertaining to Railway Sanitation

Collaborating with Joint Committee on Railway Sanitation, AAR

H. W. Van Hovenberg (chairman, subcommittee), R. C. Bardwell, C. W. Brown, Jr., R. E. Coughlan, J. H. Davidson, R. H. George, S. H. Hailey, J. P. Hanley, A. W. Johnson, O. E. Mace, G. E. Martin, W. A. McGee, G. F. Metzdorf, E. R. Morris, M. F. Neuzil, A. B. Pierce, J. M. Short, H. E. Silcox, T. A. Tennyson, Jr., R. E. Wachter.

This is a progress report submitted as information.

During the past year, the activities in connection with regulations pertaining to railway sanitation were concerned with a proposed revision of the Public Health Service Drinking Water Standards, originally published as Reprint No. 2440 from the Public Health Reports, Vol. 58, No. 3, January 15, 1943 and promulgated by the Surgeon General, United States Public Health Service, under date of September 25, 1942, and also the Sanitation Manual for Land and Air Conveyances in Interstate Traffic, originally published as Reprint No. 2444 from the Public Health Reports, Vol. 58, No. 5, January 29, 1943, and promulgated by the Surgeon General, United States Public Health Service, under date of October 2, 1942.

On July 9, 1945, a circular letter was addressed to members of the Advisory Committee on Revision of the Drinking Water Standards, on which the Association of American Railroads is represented by R. C. Bardwell, and enclosed with it was a copy of a proposed revision to the Public Health Service Drinking Water Standards as adopted September 25, 1942. The purpose of this revision was: (1) To clarify the 1942 standards in such a manner that they will be applicable for the certification of existing water

supplies without the need for any interpretative document such as State Health Officers' Circular Letter No. 85, and (2) to establish a standard that will be applicable to all public water supplies in the United States.

The significant changes proposed related to the definitions which will limit the authority of the Public Health Service to water supplies used by carriers subject to the Federal Quarantine Regulations, and a clarification of the responsibility for sanitary defects and health hazards. Several modifications were made in the wording to bring the interpretation in line with State Health Officers' Circular Letter No. 85, copy of which was published on pages 53 to 56, inclusive, of the Proceedings, Vol. 46, 1945. It is noted that the Manual of Recommended Sanitation Practice referred to in the preface of the 1942 standards and published in Reprint No. 2440 as information, will be omitted in the proposed revision in order to preclude confusion with the standards.

In view of the fact that the proposed revision dealt largely with exceptions taken to points concerning the authority of the Public Health Service and does not materially change the standards as affecting the railroads, the AAR representative on the advisory committee was recorded as registering no objection to the proposed revision.

The Joint Committee on Railway Sanitation, AAR, held conferences with representatives of the United States Public Health Service in their office at Washington, D. C., on July 26 and August 23 to consider proposed changes in the Sanitation Manual for Land and Air Conveyances which is in course of revision as are also the Interstate Quarantine Regulations. It is understood that the revised Interstate Quarantine Regulations will include some of the information formerly appearing in the Sanitation Manual that was formerly considered as recommended practice but which will then become a legal requirement. However, the committee was advised that the revisions are intended to apply to new installations and that existing installations would be deemed satisfactory except where contamination was found, and under such circumstances replacements should be in accordance with the revised provisions of the manual. The Engineering Division, AAR, was represented at these conferences by R. C. Bardwell, A. B. Pierce and H. F. King.

Of particular interest to the members of this Association was the revision of the section on hydrants which appears as Section II, Item 1 in the Sanitation Manual. A number of exceptions were taken to the original proposed revision, but it now appears that this item as revised, which will read as follows, will materially affect many railroad installations:

Section II—Item 1—Hydrants

Water hydrants, taps, or faucets shall be properly designed, located, installed and maintained to assure protection of drinking water against contamination.

Public Health Reason.—Proper design, location, installation and maintenance of hydrants, taps, and faucets are essential to avoid contamination of water delivered to such fixtures from approved sources. Contamination may occur from toilet hopper discharges either directly or by spattering and from polluted surface drainage unless hydrants are protected by vertical or horizontal distance from sources of contamination and by suitable housing where the distance obtainable does not insure positive protection. Both distance and housing shall be utilized to afford the greatest possible degree of protection. Contamination may likewise occur through openings in the supply lines such as weep-holes situated below the ground surface or in the ground water strata. The hydrant outlet must also be situated in such manner that it cannot be submerged in the event the hydrant box may become flooded either by surface drainage or by leakage from the valve.

Satisfactory Compliance.—This item shall be deemed to have been satisfied when:

(1) *Types.*—Hydrants are one of the following types (listed from a public health viewpoint in order of relative safety) and comply with all other provisions of this item:

(a) Crane type hydrants or elevated faucets served by an "above ground" supply line and not provided with subgrade weep-hole openings.
(b) Crane or post type hydrants served by an underground supply line and not provided with subgrade weep-hole openings.
(c) Post type hydrants provided with weep-holes for frost protection and served by an underground supply line.
(d) Flush type hydrants with or without frost protection.

The type (a) or (b) hydrants are obviously the safest types of installation since the possibility of contamination through weep-hole openings, the hydrant outlet, or leaks in the supply line is practically eliminated. The crane type of installation has the further advantage that the water hoses may be suspended above the ground surface and thereby further minimize the possibility of contamination of water supplied to the conveyance. Efforts should be made to secure hydrant installations of the types described under (a) and (b) wherever possible. New hydrant installations described under (c) and (d) will be accepted in those instances where no other type of installation is deemed feasible. Steps should be instituted in the case of existing installations to secure compliance with the provisions hereinafter listed.

(2) *Location.*—Hydrants are located as to minimize the possibility of contamination or accidents:

(a) The required separation of the hydrant outlet from the centerline of the nearest track shall be based on the relative elevation of the hydrant outlet to the top of the rail. Hydrants having outlets 30 in. or more above the top of the rail may be located without respect to the centerline of the track other than for reasons dictated by safety considerations. Hydrants with outlets less than 30 in. above the top of the rail shall be located at least 6 ft. from the centerline of the track in the case of existing installations. In the case of new installations, relocation of track, or major repairs where space is available, the minimum separation shall be increased to 7 ft.
(b) Hydrants located in toilet rooms, wash rooms, or similar places where danger of contamination may exist or develop shall not be used for coach watering purposes.
(c) Hydrants located within bus garages, airplane hangars, etc., and used to supply water to land and air conveyances shall be protected from contamination by such precautionary measures as may be indicated by existing conditions.

(3) *Outlets.*—Outlets are of ample size to furnish an adequate quantity of water and are designed and installed in such a manner as to prevent contamination of the water.

(a) Outlets are equipped with a type of coupling permitting quick attachment or removal of the hose. The use of threaded fittings on new installations is not acceptable, except where the hose is left permanently attached to the hydrant outlet.

(b) Outlets on all hydrants terminate in downward directed bends or goosenecks except that in the case of flush type hydrants the outlets may discharge horizontally.

(c) The outlets of all hydrants which are located less than 18 in. above the top of the rail or surrounding surfaces (platform, ballast, etc.) are protected by means of a durable close-fitting self-closing cover. The cover should be so designed as to protect the outlet against contamination while the hydrant is not in use and should enclose the outlet on all sides.

(d) In the case of flush type hydrants, the following provisions should be observed:

The upper edge of the hydrant box should extend at least 6 in. above the ballast or if located in the platform at least 1 in. above the surrounding surface. When hydrants are located on platforms used by passengers, the surrounding surface may be built up on a slope of ½ in. per ft. or less to within ½ in. of the top of the box. This will minimize the hazard to passengers and still allow for the ½ in. overlap for the cover of the box.

The hydrant box should be of durable watertight construction, provided with a self-closing cover which overlaps and extends downward beyond the edge of the box at least ½ in. An overflow opening, discharging to the surface, should be provided in the side of the box. The opening should be of sufficient size to establish a "spill line" (maximum elevation to which water can rise in the box) 1 in. below all portions of the outlet, and also should have a minimum diameter of 2 in. The opening should not be subject to stoppage or clogging. In the event the overflow is piped to a surface outlet, the pipe should be of a minimum length, consistent with ease of maintenance, should have a fall of at least ¼ in. per ft., and should be at least 2 in. in diameter. The outlet should discharge either horizontally or in a downward direction and be so located as to prevent debris or other material from falling into the outlet while the cover is open.

(4) *Drainage.*—The drainage is adequate to remove all waste water and prevent contamination of the water in the riser pipe. Underground drain lines serving either hydrant boxes or weep-holes should have a minimum diameter of 3 in. No hydrant box or weep-hole drain should connect directly to any storm or domestic sewer. Drain lines receiving surface drainage shall be construed as storm sewers.

All drain lines serving hydrant boxes and weep-holes should discharge to one of the following:

(a) the ground surface.

(b) Porous subsoil, provided that in the case of weep-holes the drain should terminate at least 10 ft. below the surface. Porosity tests should be made at the site prior to installation to determine whether the drainage is adequate.

(c) A sump from which the waste water may be pumped either to the ground surface or to a sewer through an air gap connection located above grade. Duplicate pumps should be provided.

Special consideration should be given to weep-hole drainage. The location of weep-holes in pits, ground water, or soil which is subject to contamination will not be permitted. Weep-holes may be drained to the subsoil as provided in item (b) above. Where soil conditions are not suitable, the weep-hole should be drained to a line which is entirely separate from any other drain line. This line may discharge

to a sump which also receives hydrant box drainage. The use of a line to receive both hydrant box and weep-hole drainage is not considered satisfactory.

(5) *Operation.*—The operation of all hydrants regardless of type is such as to protect the sanitary quality of the water. Post type hydrants or elevated faucets should be used for filling constant temperature bottles. The insertion of a water hose into a water bucket or constant temperature bottle during filling should be avoided because of the sanitary hazards associated with this practice.

It will be noted that under this requirement severe restrictions will be placed on the railroads covering the installation of new watering hydrants. Crane type hydrants elevated over 30 in. are seldom feasible or practical around stations or in coach yards. In most sections of the country, protection must be provided against freezing, and this means adequate drainage. With continued use of hydrants provided with weep-hole drainage, two sewer lines will be required for the entire length of the watering area, with a collecting sump and duplicate sump pumps. This will involve considerable expense at many locations. An attempt is being made to develop a hydrant which will have suitable drainage and frost proof characteristics and still avoid the necessity for installing duplicate sewer lines and sump pumps.

Another proposed revision of the Sanitation Manual discussed at the conferences involved the construction requirements for dining cars. One of the requirements in this revision calls for toilet facilities in each diner, a provision to which objection was taken by the railroad representatives and this may result in a special hearing before the Federal Security Administration.

The principal topic under discussion at the conference on August 23, 1945, was the proposed plan covering study, tests, etc., relative to the disposal of excreta from cars along the right-of-way and at terminals. This involved the suggestion, "that the ultimate solution of this problem will be the discharge of all fecal wastes from conveyances to a tank or tanks under the body of the conveyance and disposal of these wastes from such tanks to sewer system inlets in a sanitary manner". This suggestion was offered with a view to its eventual adoption as a mandatory requirement with a definite time limit for compliance.

This suggestion was discussed actively with representatives of the United States Public Health Service, leading to the proposal by the joint committee for an extensive research of the problems imposed by this proposal and at a meeting on September 28, 1945, the Board of Directors of the AAR authorized a program of research work with the employment of the necessary personnel for a thorough study of this problem.

Report on Assignment 6

Methods for Taking Water Samples

R. M. Stimmel (chairman, subcommittee), C. W. Brown, Jr., J. J. Dwyer, R. H. George, J. P. Hanley, A. W. Johnson, O. E. Mace, Ray McBrian, H. L. McMullin, R. H. Miller, M. F. Neuzil, S. E. Printz, H. M. Schudlich, J. E. Tiedt, C. P. Van Gundy, K. J. Weir.

Last year, the report of your committee was devoted to a discussion of general considerations in the taking of water samples and to the collection of samples of drinking water for use in making bacteriological examinations. This report covers the subject of boiler water samples and is presented as information.

Boiler water samples are usually collected for one of the following purposes:

Routine determination of the total dissolved solids in the boiler water. These samples are usually collected by nontechnical men and are used for check and control of road and terminal boiler blowdown.

Routine control testing by the chemical department to check and regulate water treatment and boiler blowdown.

Special investigations. Complete instructions for the collection of such samples are usually found in the methods for making the tests involved.

In general it may be stated that the boiler water sample should represent the circulating boiler water. The sample should not be diluted by steam or affected by the fresh feedwater and chemicals, especially when internal or slug treatment is used. The design of the boiler may have some effect on the circulation of the boiler water and, therefore, on the point where the sample should be taken.

Point of Sampling

For stationary boiler water sampling, it is usually possible to install a permanent sampling line which can be located at a point convenient and suitable for each individual case. A connection on a continuous blowoff line between the boiler and the blow down valve is often satisfactory.

When a special blowdown sampling line is not practicable, gage cocks, water columns, and water glass drains are used. A blowdown line other than the continuous blowdown line is not generally a suitable sampling point.

Sampling Equipment

The sampling tube should be short and as small as practicable.

Permanent sampling pipes. These should be so located that they are well below the surface of the boiler water to avoid getting steam in the water sample. They should be as far from the incoming water and chemicals as possible to avoid the inclusion of disproportionate amounts of fresh feedwater and chemicals.

Special water sampling devices or cooling coils may be constructed or purchased for collecting boiler water samples. These samplers are connected to the water column or blowdown line. The material of which the sampler is constructed should be such that it will not be attacked by the hot boiler water.

Sampling Procedures

The water column, water glass drain, etc., should be blowndown thoroughly before the sample is collected to remove sludge, stagnant water and condensate.

One of the principal sources of error in the sampling of boiler water results from the flashing of water into steam. After the water column and drains have been blown down, the sample should not be collected for a few minutes to permit drains, etc., to cool down. The amount of flashing which may occur depends on atmospheric and boiler water temperatures. The table on the next page shows the percent of flash at 212 deg. F. at various boiler pressures.

When a cooling coil or special water sampler is used, the blowoff valve should be opened and the pipe thoroughly flushed out before the sample is drawn. The sampler is then filled with boiler water and the valve between the sampler and the boiler is closed. Do not remove the sample from the sampler until it has cooled. Because of the difference in the flash when this method of sampling is used as compared with the flash with ordinary sampling, the results of the tests made by the two methods are usually not comparable.

Thermal Properties of Boiler Water

Boiler Gage Pressure	*Boiler Water Temp. deg. F.*	*B.t.u. per 100 lb. Boiler Water*	*Percent Flash at 212 deg. F.*	*B.t.u. per 100 lb. Flash Steam*	*B.t.u. per 100 lb. Liquid*
100	338	30,900	13.3	15,295	15,605
150	366	33,800	16.2	18,630	15,170
200	388	36,200	18.7	21,505	14,695
250	406	38,200	20.8	23,920	14,280
300	420	39,700	22.4	25,760	13,940
350	436	41,300	24.0	27,600	13,700

When slug methods of treatment are used the boiler water sample should be collected before treatment is applied instead of just afterwards.

For comparative results the water level in the boiler should be the same at all sampling times.

Suspended solids are usually removed by filtration.

The instructions which have been given for the collection of boiler water samples are of necessity general in nature. The application of the instructions to particular cases will depend on the judgment of the chemist. Samples for special purposes, such as the determination of dissolved oxygen, should be collected in accordance with the procedure which will usually be described in the instructions for making the particular test.

Report on Assignment 9

Methods of Removing Oily Deposits From Inside of Locomotive Boilers

J. J. Dwyer (chairman, subcommittee), W. M. Barr, R. W. Chorley, C. H. Edwards, C. E. Fisher, S. H. Hailey, T. W. Hislop, Jr., H. F. King, W. B. Leaf, W. A. McGee, A. B. Pierce, S. E. Printz, R. W. Seniff, R. M. Stimmel, R. E. Wachter.

This is a progress report presented as information.

Considerable damage to fireboxes and staybolts has been ascribed to accumulations of oil inside of locomotive boilers. Efforts have been made to minimize or eliminate damage from this cause by periodic removal of these accumulations, and this report is concerned with the various procedures that have been used and with the relative merits of each.

The damaging oil accumulations referred to have been found only in locomotives equipped with open-type feedwater heaters, in which the feedwater is heated by part of the exhaust steam being discharged directly into it. No trouble of the nature in question has been reported for engines with closed-type feedwater heaters, in which case the exhaust steam used for heating the feedwater is condensed and returned to the tender. In the latter case the oil in the steam has been found to have apparently plated out on the tender side plates. Further, in the case of the open-type heaters, investigations have shown that the trouble being discussed is not common to all locomotives with open heaters, but is peculiar to those operating in certain territories. Open-heater equipped boilers operating on water level routes have been found practically as free from oil as closed-heater equipped boilers, and leaky staybolts have been no more numerous in one

than in the other. The serious oil accumulations have been found in the open-heater boilers of locomotives operating where heavy ascending and descending grades are encountered. The explanation has been advanced that the oil deposits result from the long down grade drifts, when the drifting throttle is used while mechanical lubricators continue to operate.

Some railroads using open-type feedwater heaters on locomotives equipped with top boiler check valve systems instead of the customary side checks, have reported that no trouble is experienced from oil accumulations in the boiler, even though locomotives are operated up and down heavy grades. It would appear in this case that the oil in the feedwater probably becomes separated as it is sprayed through the steam space, and floats on the surface, rather than being swept toward the firebox with the circulating boiler water to accumulate on the sheets and bolts, as has been found where side checks are used.

Soda ash has long been used in new boilers or boilers that are being outshopped, to boil out the oil left in the processes of the boilermaking work. The relatively small amounts used for this purpose, however, were ineffective on the heavy sludge-scales under discussion. These deposits have been found in thicknesses up to 3/8 in. on radials and crown bolts and somewhat less on side sheets and in and near syphons.

To determine if soda ash in increased amounts would be effective on the heavy oil deposits, a boiler of 6000 gal. capacity was boiled out with 3000 lb. of soda ash (5.4 percent solution) and 100 lb. of sodium hexametaphosphate with the steam dome removed, using steam through the circulator and right-hand front blowoff cock to heat the solution, for 16 hours. The results showed only a little improvement to the boiler shell and no improvement to the crown bolts on which deposits were still up to 3/8 in. thick, and there was no apparent change in the physical characteristics of the deposits; they were still oily and sticky.

At about the same time, another engine of the same class was boiled out using 600 lb. of soda ash (1 percent solution). The heavy oil deposits were not affected.

Caustic soda was experimented with, using 1000 lb. in a 6000-gal. boiler, and boiling 18.5 hours with the dome cap off and using steam circulators. Some improvement was noted, and results were better than those obtained with soda ash, but heavy deposits were still present above the water line on the radials and crown bolts, and an oily coating remained on the shell courses at the same level.

Another 6000-gal. boiler was boiled using 200 lb. of sodium metasilicate and 20 lb. of a sulfonated-alcohol-type wetting agent, approximately 20 hours, using steam as the heating agent. After being washed out, this boiler was found practically clean below the water line, there being only a thin whitewash-like coating on the boiler shell, and above the water line the deposits were no longer sticky, but were rather crumbly. It appeared that additional similar treatment might eliminate these deposits.

In another experiment using the same class of boiler, a mixture of 250 lb. of trisodium phosphate, 100 lb. of sodium metasilicate, 20 lb. of sodium hydroxide, and 30 lb. of wetting agent was used. A whitewash-like coating was obtained below the water line, and the deposits above the water line were drier than when using straight soda ash or sodium hydroxide, but not as dry or crumbly as when sodium metasilicate was used.

None of the foregoing experiments produced a satisfactorily clean boiler, since some deposits, even though dried out and with stickiness removed, were found in and near the syphons. A change was made in the method of applying heat to the solution by leaving the dome cap in place, and using a low fire in the firebox and boiling under 100 lb. steam pressure, to get an elevated temperature and also a circulation of the solution through the boiler.

The conclusions arrived at from these experiments indicated that all of the procedures used had a certain degree of merit, inasmuch as all resulted in a reduction of leakage at staybolts. The greatest improvement in the elimination of leaks and obtaining a clean boiler was effected by using sodium metasilicate and a wetting agent in the proportions of 0.5 oz. and 0.05 oz., respectively, to a gallon of water, and boiling under 100 lb. pressure with fire in the firebox. This procedure has been made standard practice on the road which made the various experiments described above, and the results obtained are said to be satisfactory. The only variable now involved is the frequency of the boiling operations. Instructions call for boiling of open-heater equipped boilers at least once a year or as often as necessary, which in extremely severe cases may be every 30 days. The boilers have been rendered clean inside and water tight and are being kept in this condition by this method.

Report on Assignment 10

Means of Conserving Labor and Materials, Including the Adaptation of Substitute Non-Critical Materials, and Specifications for the Reclamation of Released Materials, Tools and Equipment

Collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR

G. E. Martin (chairman, subcommittee), I. C. Brown, C. E. Fisher, R. H. George, E. M. Grime, E. C. Harris, A. W. Johnson, Ray McBrian, G. F. Metzdorf, Theodore Morris, M. F. Neusil, W. A. Radspinner, H. M. Schudlich, J. M. Short, H. E. Silcox, T. A. Tennyson, Jr., E. R. Trodd, R. E. Wachter.

This is a progress report presented as information.

General

Informative reports were made to the Association on this subject in March 1944 and in March 1945. This report combined with the previous reports shows the progressive improvement made in the release of materials needed by the railways from the time the country entered the war until the present. In the earlier periods, it was necessary to submit to the War Production Board for approval, lists of practically all materials to be purchased and all new work was limited to projects of a highly essential nature and of moderate cost.

Under these circumstances the railways used salvaged and substitute materials to a great extent. Abandoned pipe lines were dug up and reused; worn and deteriorated pumps, valves, tanks and other items were repaired and put in shape for continued service.

Conservation Practices

The Water Service committee now has a representative on the General Reclamation Section of Committee 3A, Purchases and Stores Division, AAR to study and report on methods for salvaging additional items of water service material. It appears that this class of material can generally be salvaged best by the water service departments, as they are familiar with the requirements and use of the materials. Specifications for salvaging the numerous items of water works materials by persons not familiar with their use do not seem practicable.

Undoubtedly some of the practices for conserving material and labor which were started from necessity during the war will be continued because of their economic advantage; others will be discontinued because they are not economical. One railway reports that good results were secured from the reconditioning of water meters 5/8 in. to 10 in. in size and gate and check valves for 4-in. to 14-in. lines. New water meters were very difficult to obtain but the meter manufacturers maintained a repair service for worn meters. The meters were reconditioned at about 30 percent of the cost of new equipment and permitted the railway to go through the critical period without ordering new meters.

The gate and check valves were repaired by a commercial repair firm that has done this class of work for years for municipal, public utility and industrial plants. The firm repairs valves 4 in. to 48 in. in size and the class of work performed at a cost of approximately 40 percent of new valves was satisfactory.

The use of cathodic protection to benefit the interior of steel water tank is being extended and should result in longer life of the tank, with no loss of service time for painting the interior.

Considerable amounts of pipe lines and water mains have also been cleaned. The incrustation in the latter had been accumulating for many years when the increased demand for water revealed the extent of the loss of capacity. Many thousand feet of pipe line 4 in. to 14 in. in size have been cleaned and should have satisfactory capacity for peace time requirements for many years.

Conservation of Man Hours

In the past year the scarcity of labor has been even more troublesome to railways than the shortage of material. In order to conserve the labor that was available the use of labor-saving equipment was extended. Some examples follow:

Highway trucks were found effective in promptly transporting water service men with tools and repair parts from their headquarters to the job and return. The use of trucks reduced travel time where trains and buses were nonexistent or inadequate.

Power machinery for pipe work has been used extensively and has resulted in the saving of considerable labor, for example, ditching machines for opening trenches, bulldozers for backfilling, draglines for laying or removing pipe and (in some cases) for excavation and backfilling. The condition of the ground where the pipe is to be installed governs the type of machine that can be used to advantage. Where any of these machines can be used, the number of man-hours required is reduced considerably. The use of power-driven threading machines and welding has been effective in reducing man-hours for such work.

Power hoists with approximately 15-hp. gasoline engines were employed effectively in tank building, for raising heavy timbers, staves and floor planks and for excavations and backfilling when combined with slip scrapers and small excavating buckets.

Excavating buckets of the orange-peel type with a capacity of 3 cu. ft. were effective in cleaning intake sumps and for general light excavation when used in connection with gasoline hoisting engines and improvised booms and tackle.

Light power pumps were used to an increasing extent.

Box and ratchet socket wrenches were effective in tightening nuts on water tank hoops. The wrenches superseded the long open-end wrench which had to be reset on the nut after each partial turn. The ratchet and box wrenches permitted more wrenching time and less getting ready time in applying hoops, as they remained on the nut until it was fully tightened.

Peace Conditions

A rather sudden relinquishment of government controls on most restricted materials can be expected. Some controls will of necessity be retained, particularly those applying to imported materials, such as tin, chromium, tungsten and rubber.

It has already been announced that the Controlled Material Plan will be revoked January 1, 1946. This announcement was made prior to the surrender of Japan. Very likely a subsequent announcement will be forthcoming, moving forward the revocation date of the plan. It can be expected that conditions will change rapidly in the near future.

The question arises whether the scramble by industry for materials, after government controls have been removed, will develop into a stampede and will work to the detriment of the railroads' supply situation. It appears that some controls will be necessary as the demand for certain materials will be far greater than the supply, particularly the steel needed by the automobile industry.

Absorption of unemployment may be the deciding factor in the distribution of materials. It seems probable that the government may make arrangements whereby those industries capable of absorbing the greatest number of the unemployed may be given some form of priority for their materials.

Conclusions

1. It can be stated that the railways displayed resourcefulness and ingenuity in combining the use of salvaged and substitute materials with the limited allotment of new material to the best advantage. This combination carried them through the critical war period under a greatly increased traffic load.

2. The demand for all kinds of new materials will be very urgent for the immediate future and the railways should make plans to see that they receive a fair proportion for their requirements.

Report of Committee 14—Yards and Terminals

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Classification yards, collaborating with Committee 16.

   No report.

3. Scales used in railway service.

   No report.

4. Bibliography on subjects pertaining to yards and terminals appearing in current periodicals.

   Progress report, presented as information..... page 93

5. Produce terminals.

   Final report, with recommended Manual revisions..... page 102

6. Effect of lengthening of locomotive runs on location and arrangement of locomotive servicing facilities.

   No report.

7. Facilities for servicing streamline trains in coach yards.

   No report.

8. Engine terminal facilities.

   No report.

9. Facilities for conveyor handling of l.c.l. freight at freight houses, collaborating with Committee 6.

   No report.

AREA Bulletin 455, November 1945.

10. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.
No report.

THE COMMITTEE ON YARDS AND TERMINALS,
W. J. HEDLEY, *Chairman.*

Herbert Lawrence Ripley

Herbert L. Ripley, retired contract agent of the New York, New Haven & Hartford Railroad Company, and an outstanding figure in railroad valuation circles, died at New York City on December 1, 1944, after a long illness. He was born at Holden, Maine, February 2, 1874, the son of Martin William and Almatia (Copeland) Ripley. His education included high school, private instruction and the Lowell (Mass.) Institute. He started his railroad career in 1893 as transitman with an interurban trolley line and entered the service of the New York, New Haven & Hartford Railroad in July 1898. Following a wide experience in heavy construction work on that road, and several promotions, he was appointed engineer of construction in 1909. The rest of an active career was devoted to the New Haven Railroad, except for a period of about a year and a half when he was engaged on heavy railroad construction in Vermont and New Hampshire for a contractor.

Following the passage by Congress of the Valuation Act in 1913, he was appointed valuation engineer of the New Haven Railroad and all its subsidiary companies, a position he held until October 1929. During that period he was a member of the General Engineering Committee of the Presidents' Conference Committee on Valuation, and chairman of its subcommittee dealing with Valuation Order No. 3. As chairman of this committee he became a nationally known figure in valuation circles. During the period of federal control he was made corporate chief engineer, and on the request of the late Judge C. A. Prouty, then director of the Bureau of Valuation as well as director of the Division of Accounts, he also represented the director general of railroads. At the end of federal control he was appointed corporate and valuation engineer, which position he held until 1929 when he became assistant to vice president. In 1935 he was appointed contract agent, which position he held until he retired on July 1, 1943, because of illness.

He was a member of the American Society of Civil Engineers, the Connecticut Society of Civil Engineers, the Affiliated Technical Societies of Boston and the American Railway Engineering Association, and during federal control a member of the Railway Corporate Engineers Association, a member of its executive committee and for the latter part chairman of its finance committee.

A member of the American Railway Engineering Association since 1910, he served on Committee 2—Ballast, acting as chairman from 1920 to 1921, and on Committee 14—Yards & Terminals from 1923 to the time of his death, acting as chairman from 1931 to 1933. He was also a member of Committee 26—Standardization for two periods.

Mr. Ripley married Leila Frances Drake January 22, 1902. Her death on October 23, 1932, was a very great blow to him. He is survived by his daughter, Eleanor C. Ripley, with whom he was living in New York City at the time of his death. He will be long remembered on the New Haven Railroad and by his many friends in valuation circles and in the AREA, where he was so active and well liked.

Report on Assignment 4

Bibliography on Subjects Pertaining to Yards and Terminals Appearing in Current Periodicals

E. E. R. Tratman (chairman, subcommittee), Hadley Baldwin, F. T. Darrow, M. H. Dick, F. A. Hess, J. E. Hoving

While the bibliography supplement to the Yards and Terminals committee report in 1946 follows the usual classification as to published information, it has been expanded by special request to include notes of published matter relative to the astonishing accomplishments of the American and Allied forces in railroad and engineering work, here and in many foreign countries, in the prosecution of World War II. Mention may be made also of two books. "Railroads at War" by Kip Farrington and "Bulldozers Come First" by a group of editors of Engineering News-Record who were with the troops in several fields of action.

In connection with the design and modernization of railway stations, it is interesting to note that stations are featured in the publicity campaign conducted jointly by the four companies whose lines comprise practically the entire English railway system. For instance, one advertisement shows an imaginary station and the text says, "Shape of things to come. New stations will be one of the orders of the day when the railways get busy on their peace program. The clean designs of modern construction will combine pleasant surroundings for the passenger with time-saving efficiency."

Increasing use of loud speaker instruments at large English stations was described to the Institution of Railway Signal Engineers by W. J. Claridge of the Great Western Railway. He urged the importance of voice training for this service and also the study of the acoustics and other features of individual stations. In the discussion it was suggested that in view of the usual noisy conditions, it might be better to use train indicators supplemented by adequate signs on the platforms and on the standing trains.

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Report on Assignment 5

Produce Terminals

W. H. Giles (chairman, subcommittee), A. L. Becker, G. F. Hand, W. J. Hedley, J. S. Knight, E. E. R. Tratman.

Last year your committee submitted a progress report on this subject (Proceedings, Vol. 46, 1945, page 81). In that report it was pointed out that a definite line of demarkation exists between the services to be provided by the railway facilities and the services to be provided by the wholesale market facilities, and that the general term "Produce Terminal" should be considered to include at least two separate and distinct facilities.

Your committee recommends that the material now contained in Section 36 of the Manual, pages 14–28 to 14–31, inclusive, be rearranged, expanded and made to conform with the principle of independent units so that it will read as follows:

36. Produce Terminals

361. General

(a) Produce terminals are designed for expeditious and economical delivery of fruits, melons, vegetables, and sometimes butter, eggs and live poultry.

(b) Terminals should be located and designed to handle peak business.

(c) A union terminal serving the entire trade of a community is preferable.

(d) The location must be convenient for dealers, with easy access over wide and well improved highways and easy gradients. It should have convenient railway connections. A location adjoining a railway terminal yard is advantageous.

362. Function of Railway and Marketing Facilities

A produce terminal should be considered to include (a) railway facilities and (b) wholesale marketing facilities.

(a) Railway facilities include the primary units for handling carload shipments prior to distribution or reconsigning. Any or all of the following facilities may be required:

1. Receiving and delivery yard.
2. Hold and inspection yard; with or without supplemental classification tracks.
3. Team yard.
4. Buildings for sorting, reconditioning and transferring of lading.
5. Administration building.
6. Motor truck scales.
7. Buildings for coopering and supplies.
8. Buildings for heaters and supplies.
9. Rest rooms for yard crews, stevedores, truck operators and laborers.
10. Incinerator.
11. Communication facilities.
12. Yard lighting.
13. Icing facilities.
14. A track system for serving the yards.
15. A system of driveways for movements to and from the team yard and the hold and inspection yard.
16. Fire protection facilities.

(b) Wholesale marketing facilities include units for the sale and distribution of produce and may be situated adjacent to or within easy access of the railway facilities. In either case certain units should be served directly by railway tracks. Any or all of the following units may be required:

1. Buildings divided into separate stores.
2. Buildings for display and private sales.
3. Buildings for display and auction.
4. Auction rooms.
5. Office, restaurant, etc.
6. Cold storage warehouse.
7. Bulk delivery platforms.
8. Live poultry platforms.
9. Ripening facilities.
10. Reconditiong facilities.
11. Motor truck and other scales.
12. Incinerator.
13. Communication facilities.
14. Fire protection facilities.
15. Farmers' market.
16. A railway track system serving the buildings.
17. Driveways serving the buildings.

363. Track Layout

(a) The track layout should be as compact and flexible as possible, and extensive enough to take care of traffic without delay. It is governed by the number of cars handled at peak periods, the different kinds of produce received, and the average standing time until cars are released.

(b) A receiving and delivery yard is sometimes desirable for receiving transfers from various roads and for assembling outbound empties and reconsigned cars.

(c) A hold and inspection yard is sometimes provided. This yard should have two-lane driveways between pairs of tracks to permit access for inspection and icing from trucks. Inspection platforms are sometimes provided. It may be a separate yard or combined with the receiving and delivery yard or with a small classification yard.

(d) Team yards should have ample standing capacity. Extremely long tracks should be avoided.

(e) Track centers should be not less than 13 ft.

364. Buildings

(a) Ample floor space should be provided for mechanical handling from cars to warehouse floor, display of produce and assembly of various lots for delivery to trucks.

(b) The column spacing should be given careful study and be as wide as possible, consistent with economic design.

(c) The back-up space for trucks should be as liberal as possible.

365. Driveways

(a) Team yard driveways should be hard-surfaced and have at least 45 ft. clear width between cars.

(b) Driveways between buildings or between a building and a team track should have preferably a clear width of 80 ft.

(c) Inspection and hold yard two-lane driveways may have a clear width of 22 ft. between cars.

366. Platforms

(a) Inspection platforms should be 4 ft. 6 in. to 6 ft. wide, 3 ft. 3 in. above top of rail, and at least 5 ft. 9 in. from the center line of tangent track. Platforms should be covered and lighted.

(b) Platforms used exclusively for handling live poultry should be 16 ft. to 20 ft. wide, 3 ft. 5 in. above top of rail, and at least 5 ft. 9 in. from the center line of tangent track. Platforms should be covered, and light and water should be provided. Roof supports should be located to minimize interference with handling crates. Space for crate storage and repairs is usually required. Facilities for handling live poultry business should be accessible for trucks, but should be located as far as possible from produce houses.

(c) House platforms, when served by both highway vehicles and railway cars, should be 4 ft. above top of rail and 8 ft. from the center line of tangent track.

(d) Clearances must comply with state regulations.

367. Icing

All cars in team and hold and inspection yards should be accessible for icing, which is usually done by contract with local dealers. Access may be from narrow driveways or from icing platforms.

368. Garbage and Refuse Disposal

Cars should be thoroughly cleaned after unloading, and all refuse and garbage removed from platforms, buildings, etc. Special equipment such as sweepers, dump carts, etc., should be provided in large terminals. Garbage may be handled by city collection, by contract, or incinerated. An incinerator, if required, should be of ample capacity to handle each day's collection in 6 to 8 hours, conveniently located, and designed to burn garbage having a high water content.

369. Miscellaneous

(a) Ample drainage is essential for buildings and yards.

(b) Floodlighting the entire area is desirable in addition to local lighting.

(c) The entire area should be strongly and closely fenced to prevent trespass.

(d) Definitely assigned entrances and exits should be provided.

(e) A cold storage warehouse, if required, should have suitable track service and convenient means of communication with other buildings.

(f) Adequate parking space should be provided.

(g) Motor truck scales, when required, should be located at a point convenient for the drivers and near the freight office. The location should not interfere with truck movements in the driveways.

Report of Committee 25—Waterways and Harbors

BENJAMIN ELKIND, *Chairman,*
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W. D. FAUCETTE
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E. F. WENDT
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Study of metal and other protective casings for pier structures under water.

   No report.

3. Prepare abstract of flood control acts and outline procedure under the acts, collaborating with AAR Committee on Waterway Projects.

   Final report, presented as information..... page 106

4. Reasonable life of steel casings immersed in sea water.

   Final report, presented as information..... page 108

5. Prepare abstract of the Truman–Hobbs Act and outline procedure under the act, collaborating with AAR Committee on Waterway Projects.

   No report.

6. Procedure with regard to rivers and harbors projects, collaborating with AAR Committee on Waterway Projects.

   No report.

THE COMMITTEE ON WATERWAYS AND HARBORS,
BENJAMIN ELKIND, *Chairman.*

AREA Bulletin 455, November 1945.

Report on Assignment 3

Prepare Abstract of Flood Control Acts and Outline Procedure Under the Acts

Collaborating with AAR Committee on Waterway Projects

P. T. Simons (chairman, subcommittee), Benjamin Elkind, D. J. Brumley, G. F. Hand, N. D. Hyde, F. D. Kinnie, F. E. Morrow, J. Y. Neal, W. G. Nusz, L. A. Olson, F. R. Paisley.

This is a final report, presented as information.

Legislation

1. The Flood Control Act of May 15, 1928, as modified by Public Law 678, 74th Congress, June 15, 1936, on Mississippi River below Cape Girardeau, Mo., in seven states—Missouri, Illinois, Kentucky, Tennessee, Arkansas, Mississippi and Louisiana—is the first act which really authorized flood control work and appropriated federal funds directly for large scale construction. About 3,000 miles of tracks are involved belonging to 12 railroad companies which operate nearly 53,000 miles of tracks in about 20 states.

2. The AREA Board of Direction appointed a committee on the Mississippi valley flood of 1927, composed of 12 chief engineers of the lines involved. This committee named a subcommittee of 9 members who prepared and published, in January 1928, a bulletin of 111 pages on that flood. Ever since that time, the owners of these 12 railroads have been concerned with flood control measures especially in the lower Mississippi River basin.

3. On June 22, 1936, a nation-wide Flood Control Act was approved; namely, Public No. 738, 74th Congress. Section 1 of this act ends with this sentence:

> "The federal government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected."

4. This act was amended or had new provisions added in 1937, 1938, 1939, 1941, and 1944. These Acts include—

Public Act	No. 51	75th	Congress	April	27, 1937
" "	No. 406	75th	"	August	28, 1937
" "	No. 591	75th	"	June	11, 1938
" "	No. 761	75th	"	June	28, 1938
" "	No. 396	76th	"	August	11, 1939
" "	No. 228	77th	"	August	18, 1941
" "	No. 534	78th	"	December	22, 1944

Procedure

5. As the course to be taken by individual companies rests so largely with the managements of the railroads themselves, it is difficult to outline a procedure in general terms. The following outline is typical for proposed projects where local interests have an opportunity to give their views on what work is necessary and desirable.

6. Investigation of a project starts with authority by Congress, and one of the first steps is the holding of public hearings by the United States district engineer, property owners and others interested being notified that they may appear and make oral state-

ments, submit written statements or data in connection with the extent of the protection desired or offer objections to the proposals brought up at the hearing. It is of prime importance to be represented at the first hearing, either to submit a statement or to get on record in order to fully protect the railroads' interest. If matters develop at the hearing that make it desirable or necessary to submit additional data or information, the district engineer will grant a reasonable time for the preparation of a brief to be submitted to him.

7. The district engineer's report goes to the division engineer, who may follow any one of three procedures:

(1) He may make an unfavorable report.
(2) He may make a report partially unfavorable.
(3) He may approve the project report, in which case the report goes to the chief of engineers, who, under the law, sends it to the Board of Engineers for Rivers and Harbors.

In either case (1) or (2), above, the division engineer sends notices to all interested parties, who may ask for a further hearing. The division engineer also sends out a public notice stating what action he has taken on reports being forwarded to the chief of engineers at Washington, D. C.

8. The Board of Engineers for Rivers and Harbors is comprised of seven U. S. Army engineers from various parts of the United States, with the senior member, one resident member and a civilian secretary who have an office in Washington, D. C. This board likewise follows the same three methods of procedure as outlined above for the division engineer, including further hearings as may be requested by interested parties.

If the board approves a project, the report is returned to the chief of engineers who forwards it to the governors of the affected states, and, if the project is west of the 97th meridian, the report must go to the Secretary of the Interior. It is also necessary to have the approval of the Bureau of the Budget. The report then goes to the Speaker of the House, or the chairman of the committee requesting the report, as the case may be.

9. The House Committee on Flood Control and the Senate Committee on Commerce may both hold hearings on omnibus flood control bills and on separate flood control bills. If a hearing on any project is desired, a request to that effect should be made to the chairman of the House committee.

10. After formal approval of a project, the House Committee on Flood Control can adopt a resolution requesting a review of the previous reports involving that project, if asked to do so by the local interests who desire a change in the plans.

11. After a project is authorized by Congress, the only opportunity for a major change is another act of Congress. Minor changes can be made at the discretion of the Secretary of War.

Construction funds must still be appropriated by Congress for an authorized project before work can proceed.

12. Under the present AAR zone organization, any and all railroads interested or affected by a proposed project should receive notice of hearings held by the district engineer and have the opportunity to be heard, or request time to prepare a brief if developments at the hearing indicate that this would be desirable or necessary.

Report on Assignment 4

Reasonable Life of Steel Casings Immersed in Sea Water

W. D. Faucette (chairman, subcommittee), D. J. Brumley, Benjamin Elkind, J. D. Moffat, W. G. Nusz, F. N. Nye, G. P. Palmer, J. P. Ray, E. F. Wendt.

This is a progress report, presented as information.

As stated in the report in the Proceedings, Vol. 42, 1941, page 60, your committee has been awaiting with interest the results of exposure tests conducted by the Beach Erosion Board of the U. S. Corps of Engineers as an important feature of a study of sea water corrosion which the board has been carrying on. However, because of the war the board has been inactive and no data have been made available for the use of your committee. It is hoped that in another year or two a more complete report can be submitted.

It has come to the attention of the committee that an article bearing the title, Corrosion of Steels in Marine Atmospheres and in Sea Water was prepared for the Electrochemical Society by C. P. Larrabee of the Corrosion Research Laboratory, Carnegie–Illinois Steel Corporation. This article refers to a report on certain corrosion tests made at Kure Beach, N. C., and with the consent of the Carnegie–Illinois Steel Corporation, your committee presents below abstracts from Mr. Larrabee's report.

Table VII.—Corrosion Tests in Sea Water at Kure Beach, N. C.

Composition				Duration	Corrosion Rate		Maximum Pitting	
Cr.	*Ni.*	*Mo.*	*C.*	*Years*	*mg. per dm.²* *per day*	*in. per year*	*mm.*	*in.*
2.9	...	..	0.08	4.62	14	0.0026	0.94	0.037
6.0	...	..	0.08	4.62	16	0.0029	2.23	0.088
13.15	...	..	0.08	1.56	12	0.0022	1.48	0.058
17.3	...	..	0.10	1.56	9	0.0017	2.74	0.108
18.5	9.0	..	0.05	1.88	0.5	0.0009	3.3	0.130
18.8	10.2	2.7	0.05	5.26	0.4	0.0008	0.94	0.037
24.0	21.0	..	0.12	2.71	0.7	0.0013	0.48	0.019

In Table VII are shown typical results of tests at Kure Beach, N. C., on 30.5 cm. (12 in.) square stainless steel panels in sea water at low velocity (1 to 2 ft. per sec.) under conditions permitting attachment and growth of marine organisms. It is seen that both 13 percent and 17 percent chromium steels lose many times as much weight per day as 18 percent chromium-8 percent nickel steel or materials containing more of these two alloying elements.

However, due to the oxygen-concentration cells set up by certain types of sea growths, the presence in 18/8 type steels of about 3 percent molybdenum is essential to lessen the danger of excessive pitting. Alloys containing 25 percent chromium and 20 percent nickel are reasonably free from excessive pitting, but even these alloys are occasionally found to be pitted. As mentioned previously, a high polish is desired to resist tarnish in the atmosphere, but in sea water at low velocity a highly finished surface appears to be somewhat more liable to pitting than a rougher one.

As indicated, the stainless steel performs much better when in contact with sea water at high velocities, e.g., over 5 ft. per sec. (1.5 m. per sec.) as in the case of pump impellers in fairly continuous operation, and of tubes and piping through

which sea water flows continuously at high velocity. Stainless steel impellers have been found to be particularly satisfactory in pumps handling polluted harbor waters, especially when hydrogen sulfide, which accelerates attack on copper-base alloys, is present.

Four precautions in the use of stainless steel in sea water are advocated:

1. Avoid applications at low velocity (under 5 ft. per sec.) and especially where marine organisms may become attached to the alloy surface and promote localized attack.

2. Avoid crevices which may become the seats of destructive corrosion as a result of the action of oxygen-concentration cells. If crevices must be tolerated, endeavor to inhibit such corrosion by the use of some material such as petrolatum.

3. See that the alloy is properly heat treated, especially after welding or other heating, unless the alloy contains a stabilizing element such as columbium or titanium which permits elimination of such heat treatment.

4. Favor combinations with equal or larger areas of steel or other less noble metals, e.g., zinc, and avoid combinations with relatively large areas of copper-base or nickel-base alloys.

Summary and Applications

1. The attack on all steels immersed in sea water varies with local conditions.

2. The rate for plain steel varies between 11 and 42 mg. per dm.^{2} per day (0.002 and 0.0077 in. per year average penetration).

3. The average rate for plain and for most low alloy steels is about 22 mg. per dm.^{2} per day (0.004 in. per year average penetration).

4. Under most conditions, substitution of low alloy steels can be justified only by tests which closely resemble service conditions.

5. The rate of attack for steels exposed between high and low tides varies with the locality, pollution of water, and oil which may form a protective coating. In warm humid atmospheres, corrosion may be accelerated appreciably. In some tests the most severe corrosion has occurred just above normal high tides.

6. The presence of 2 percent to 3 percent molybdenum will usually prevent seriously deep pitting of chromium-nickel steels containing 18 percent chromium, 8 percent nickel; while molybdenum-free steels containing 25 percent chromium and 20 percent nickel are reasonably immune from excessive pitting attack.

Mr. Larrabee calls attention to a statement that appears on page 136 in the report, and your committee quotes from his observations, to-wit:

. . . "The average rate of attack on plain steels, 20 mg. per dm.^{2} per day (0.0036 in. per year average penetration) can be assumed with reasonable security under most conditions of immersion."

Moreover, in many cases unprotected structural steel is subject to excessive pitting. Therefore, frequently the "average penetration" will be exceeded many fold by the "deepest pit." Usually pitting rates show a tendency to slow down as time progresses which is another of the complicating factors that must be taken into consideration when estimating probable service life of steel structures immersed in sea water.

This full report can be reviewed upon application to Mr. Larrabee, or to the Electrochemical Society, whose address is Columbia University, New York City.

Dr. W. F. Clapp, in the corrosion course of Stevens Institute of Technology, Hoboken, N. J., has written an article on "The Effect of Macro-Organisms on Metals in Sea Water. While this may not be precisely included in the subject assigned to our committee, it was so interesting that it seemed proper to quote the following paragraphs from Dr. Clapp's paper, with his consent:

Past Records

Until very recent years, little has been known regarding the effect that marine organisms might have on metals and alloys.

Published observations have been contradictory. Many reports have stated that marine growths provided protection to the metal beneath, while an equal number state that such growths accelerate corrosion.

At the present time it appears that both observations are true—that under certain conditions certain organisms may provide protection, while the same organisms under other conditions may cause corrosion far in excess of normal rates for the same metal.

The fact that marine growths appear to reduce corrosion of metals has led some investigators to study the possibility of artificially providing a protective coating similar to that deposited by some species of barnacles, oysters and similar organisms.

Fouling Organisms

Organisms are exceedingly abundant in salt water. Many thousands of species of invertebrate animals and marine plants have been described and named. Many species are so abundant that the color of the water is affected. In some locations, even far from shore, pelagic marine life is so prolific and forms such dense mats on the surface of the ocean that the speed of a vessel may be appreciably reduced.

Only an infinitely small number of the many thousands of different kinds of these animals and plants should be considered as fouling organisms. The vast majority are free swimming and do not possess the necessary organs or have the power to become attached to any material. Others must burrow in mud, sand, or some other substance in the ocean for protection in order to survive.

None of the vertebrates, such as the fish or mammals which are so plentiful in salt water are capable of maintaining a permanent foothold on any material and none, therefore, should be considered as being true fouling organisms.

Organisms which might affect metals or other submerged materials in salt water can be roughly divided into three groups as follows:

Sessile Organisms.—This group is restricted to organisms which cannot survive without becoming firmly attached to a suitable base.

All organisms which are found firmly attached to a material in salt water secured this attachment early in life while still in a very minute embryonic form. No organisms have the ability to become firmly attached to any base after having passed from the minute embryonic form to the mature form.

No true fouling organism can change its position once it has become attached. Very few can survive if they become separated from the base upon which they have grown, and none which have become attached have the power to secure a new foothold.

The following list includes most of the common forms of true sessile fouling organisms:

1. Marine algae, including such forms as ceramium, fucus, polysiphonia, ulva, etc.
2. Calcareous and siliceous sponges.
3. Coelenterates, such as tubularia, a plant like animal, bougainvillia, campanularia, and also some of the calcareous corals.
4. Certain worms which form calcareous, sand, or mud tubes.
5. Barnacles.
6. Several species of mollusks, such as the oyster.
7. Colonial animals belonging to the bryozoa.
8. Sea squirts.

All of the above are completely sessile fouling organisms. It is this group which is principally responsible for any effect that any organisms may have on metals.

There are, however, other animals which may occasionally contribute to some extent, since they are semi or optionally motile.

Corrosion Due to Biological Factors

Oxygen Concentration Cells.—Unequal adherence of any portion of the base of a fouling organism may be caused by an original natural unevenness of the surface or by corrosion having started before the organism obtained a foothold. It also may be caused by one or more micro-organisms, such as diatoms or foraminifera, having become attached to a portion of the area over which the macro-organisms grows. An uneven growth on a portion of the metallic surface over which a macro-organism extends its base, may result in unequal adherence of the latter. Because of this unequal firmness of attachment beneath some portions of the base, oxygen concentration cells may develop, resulting in corrosion.

Chemical Corrosion.—Another entirely different and very important type of corrosion is encountered when, in the process of expansion of the base by growth, an organism completely surrounds and covers a later arrival, or smaller, organism. Deprived of water necessary to aerate its gills and to provide food, the covered organism quickly dies. Degeneration sets in followed by the probable production of hydrogen sulfide. An acid condition results which causes accelerated chemical corrosion.

It has been observed in one series of tests that of two identical panels of ferrous metal, one of which was cleaned of all growth and corrosion products once a year for several years, and the other continuously submerged without cleaning, that the latter showed a greater weight loss. Since the corrosion product has been considered to be of a somewhat protective nature, that is, that the rate of corrosion decreases somewhat in time, it is possible that the higher weight loss in the panel from which the growth had not been removed might be due to the effect of the decaying matter buried in the growth of organisms.

Protective Coatings—Some organisms, particularly certain species of barnacles, such as balanus eburneus, are capable of penetrating or otherwise damaging protective coatings on metals. In the process of growth and the spreading out of the base of the organisms over the surface of any material there is also exerted a very strong downward pressure. As a result of this pressure, the outer edge of the base may penetrate the film of a protective coating. On some materials that penetration may proceed to the base metal. As the diameter of the base increases, the paint film is pushed up on the sides of the growing organism. In the case of some of the thick bituminous enamels and asphalt coatings, the organisms may penetrate through one quarter of an inch of a coating to the base metal. On the death of the organism the

remaining animal matter is quickly removed by scavengers and the bare metal is exposed. Oxygen concentration cells develop and accelerated corrosion follows.

On a hard, dense protective coating, penetration by these organisms is prevented, but in many cases the downward pressure exerted by the growing organism results in a bond between the base of the organism and the protective coat, of greater strength than the bond between the protective coat and the metal. When any action dislodges the organism, the complete paint system remains attached to the organism rather than to the metal. Accelerated corrosion of the exposed metal follows.

It has been found, at least with some paint coats, that the difference in the firmness of adhesion of the paint coat beneath the base of an organism and that of the paint coat outside of, but adjacent to the base of the organism results in accelerated corrosion in the form of pits directly beneath the organism even while the paint system and the fouling organisms are apparently undisturbed. This may be the result of oxygen concentration cells having been formed beneath two adjacent areas, over one of which the paint coat is firmly adherent and at least somewhat impervious, while in the other, the paint coat, because of the action of the fouling organism, is not adherent.

However, in this particular type of corrosion, the few observations which have been made have all been connected with paint coats containing corrosive pigments which may have been responsible for this accelerated corrosion. In either case, however, the fouling organisms can be considered as primarily responsible.

It is recommended that any interested engineer communicate with Dr. W. F. Clapp (William F. Clapp Laboratories) Duxbury, Mass., for any further exploration of this subject.

It is the purpose of your committee, prior to the 1947 convention, to communicate with the United States government departments to see if any further explorations and studies have been made on the subject of this report.

It is the request of the committee that if any members of the association have had experience, or given any study to this subject in the last 5 or 10 years, they communicate with the chairman of this subcommittee, giving him the benefit of their knowledge on the subject.

Report of Committee 6—Buildings

H. C. Lorenz, *Chairman*
F. H. Alcott
C. M. Angel
G. A. Belden
C. E. Booth
C. M. Burgess
H. M. Church
A. C. Copland
C. O. Coverly
L. B. Curtiss
H. G. Dalton
A. G. Dorland
W. T. Dorrance
J. P. Gallagher
W. G. Harding
A. T. Hawk
E. G. Hewson
V. V. Holmberg
C. D. Horton
N. D. Howard
W. V. Kerns
L. P. Kimball
L. H. Laffoley
E. S. Lank
F. H. Lovell
B. M. Murdock
B. R. Prusak
J. B. Schaub
E. W. Scripture, Jr.
R. H. Snyder
J. E. South
A. L. Sparks
O. W. Stephens
A. B. Stone
S. G. Urban
W. E. Webb
J. W. Westwood
O. G. Wilbur
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Preparation of specifications for railway buildings.

   No report.

3. Color dynamics as an aid to efficiency.

   Final report, presented as information..... page 114

4. Prefabricated buildings for railway use.

   Final report, presented as information..... page 117

5. Fire Retardant Coatings.

   No report.

6. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

   No report.

The Committee on Buildings,
H. C. Lorenz, *Chairman.*

AREA Bulletin 456, December 1945.

Report on Assignment 3

Color Dynamics as an Aid to Efficiency

C. M. Angel (chairman, subcommittee), H. M. Church, C. O. Coverly, L. B. Curtiss, A. G. Dorland, N. D. Howard, W. V. Kerns, B. M. Murdock, R. H. Snyder, O. W. Stephens.

This is a final report presented as information.

The possibilities for more economical and efficient operation of various branches of the railroad industry are constantly expanding through extensive research and intelligent cooperation of manufacturers and users. This report has been written for the purpose of establishing facts pertaining to color painting as a new phase in the construction and maintenance of railroads.

Paint, of course, is the oldest and most widely used material for protective and decorative purposes; however, only recently has it been determined that the proper blending of colors, which has been termed "color science," would increase production, reduce personal injuries, provide better working conditions and also improve morale. Color science can be used not only to produce a pleasing contrast, but also to enhance the quality of light, as every color has a definite wave length or light reflection value. In waiting rooms, for instance, the ticket offices or other facilities are usually built along one wall, which, if painted a color different from the end walls, instantly becomes prominent and eye-catching. When this color is one which will blend or complement other colors, a psychological effect results which reduces nervous tension and imparts a feeling of relaxation and cheerfulness. For rest rooms, bright, harmonizing colors are not only cheerful and restful—they are sanitary as well and react on the average individual by making him more careful and interested in maintaining cleanliness.

Color can either stimulate or depress; it can focus attention upon an object or cause it to recede or become sublimated with surrounding colors. It can be used to emphasize safety, or to induce cheerfulness. All trucks which are used for loading and unloading express stand out prominently if painted focal yellow and striped in black. The painting of traffic lanes will aid in reducing congestion on platforms and elsewhere. Doors stand out clearly when painted in colors. The advantages are innumerable.

Without the use of color in this report it is difficult to demonstrate the pleasing effects produced by contrasts of color. It is also necessary to bear in mind that many different color arrangements are recommended for various types of work, and for this reason no rule can be set up which would apply to every location. Rather, each problem must be worked out to suit the individual case, using colors which will provide a distinct color difference between working and surrounding areas and using light colors at proper locations so as to reflect the necessary brightness without extreme glare.

Different Colors

Colors used in this type of painting may vary in shades, depending on the manufacturers' specification; however, the colors generally used are ivory, buff, green, gray, vista green, blue, yellow, beige, red, orange, dark gray, cascade blue, sea foam green, sand, suntone, rose tan, stratosphere gray, eye-rest green, cruiser gray, dixie gray, pewter gray, tile red, light oak, dark oak, white, yellow, and orange.

Of the colors listed, those embracing ivory to dark gray, inclusive, should be considered for machinery and equipment; the range from cascade blue to eye-rest green, inclusive, for walls and ceilings; cruiser gray to dark oak, inclusive, for floors and dados; and white to orange, inclusive, for zone marking.

Before undertaking to apply any color scheme in the painting or repainting of a station, shop or other facility, those responsible for the selection of the paint should confer with a representative of a paint manufacturer who is well informed regarding the blending of the various colors. They should also give consideration to the type of work performed in the building, as well as the characteristics of the personnel employed. Thus, it has been demonstrated that for shops employing a preponderance of men greens, browns, blues, and such colors are preferred; however, where women are working, more delicate shades such as turquoise and peach are desirable.

However, a general plan to be followed in the selection of colors would be to paint the critical parts with a color which would stand out to the vision, while other parts should be in blending colors which will serve as a background and lend contrast to the critical parts. Colors selected for the walls should reflect as much light as possible, yet not subject the workers to harsh changes in brightness. The colors should blend with the wainscoting. In ceiling painting, where a large amount of steel work or pipes is visible, blue or similar colors are suggested as these colors seem to make the ceiling recede. If the ceiling, pipes, or steel work are high over the workers' heads, consideration can be given to a white ceiling and aluminum for the pipe and steel work. It is always best to use red to designate electrical conduit, switch boxes and similar equipment.

Practical Test on How Selected Colors Harmonize

When colors are selected and there is some doubt as to how they will harmonize, a check can be made in the following manner: A box should be built of wall board or like material, a suggested size being 12 in. by 18 in., with one side of the box open. The interior of the box is painted with the selected colors, the top representing the ceiling, the back and ends the walls, and the bottom the floor. When the painting is completed and the dado stripes have been applied, the result can be viewed to ascertain how the colors harmonize. A better plan would be to cut pieces of board to represent the ceilings, walls, and floors, which can be placed in the box. These boards can be painted with various colors, so that different arrangements may be tested until the desired color scheme is found. A small block of wood, representing a machine, can be cut to scale and painted, and set on the floor of the box to ascertain how it blends in with the walls, ceiling, and floor.

Light Reflection Values of Paint Colors

In this report particular emphasis has been placed on the reason for and the advantages of color painting, however, one of the primary objectives of painting the walls and ceiling is to reflect light in which to work. Consequently, it is of value to consider the light reflection values of the various colors, when making a selection to harmonize with the color scheme. The generally accepted light reflection values are as follows:

Color	*Percent of Light Reflection*
White	89
Light yellow	78
Ivory	78
Light cream	77
Peach	72
Rose	66
Pale green	62
Light blue	62
Cream gray	61
Light gray	57
Buff	55
Aluminum	42

The light reflection value of colors is very important in view of the fact that daylight illumination diminishes sharply from 90 foot-candles at the window of a typical room to about 5 foot-candles at the inner wall; and that a dark ceiling absorbs light and causes shadows to fall from machines located near windows and that a white ceiling reflects light thus reducing the shadows to a minimum.

Paint Surface

After the colors have been selected the question of surface texture must be disposed of; that is, whether a flat, semigloss, or high gloss paint should be used. The semigloss and high gloss paints will stay clean longer as they will not collect dust as fast as a flat or rough surface. Therefore, for all practical purposes it appears that the semigloss paint should meet the requirement; however, the selection should be based entirely on the users' preference.

Color Harmony

Determination of color harmony will always be based upon individual taste unless the opinion of a color expert is to be considered. In Exhibit "A" many color arrangements are tabulated with the thought that one or more of them could be selected when consideration is being given to the scheme of color painting.

Application of Color Painting to a Test Laboratory

As a practical example of the application of color painting, the following account is given of the repainting of a railroad laboratory. Until recently this modern testing laboratory, built in 1929, had been painted more or less to a standard plan, that is, the machines were gray and the walls, window frames, and steel work a flat nonreflecting paint. In addition to this, in the chemical laboratory the work benches and tables were dark oak and had been varnished. As this style of painting was low in light reflecting qualities, the laboratories always had a dark, gloomy appearance and gave the impression of a perpetually cloudy day.

When the question arose as to repainting these facilities, attention was given to color painting, as this would not only result in a brighter aspect to the surrounding working areas, but would have a beneficial effect on the workmen through their eyes. It is an established fact that proper colors give people "a lift," whereas wrong colors have a disturbing effect.

An investigation was made to secure the most desirable colors for laboratory work which would harmonize with the building construction. Therefore, it was necessary to select colors to separate the critical from the noncritical parts of test machines, walls, and ceiling to bring out the best in the daylight and artificial lighting.

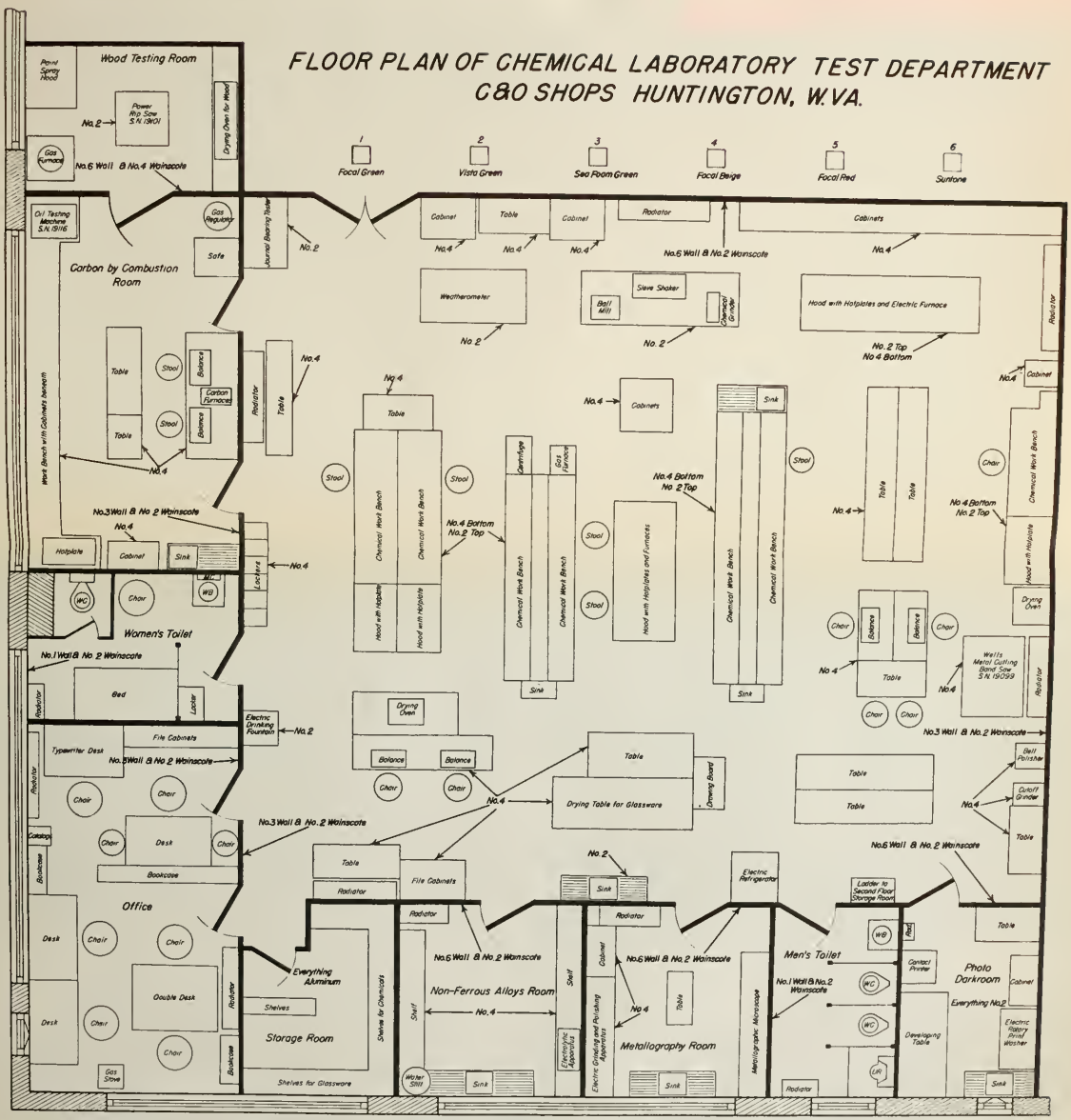
Obviously, color illustrations would afford the only effective means of demonstrating what was accomplished in painting these laboratories, but as their use is out of the question it has been necessary to rely on the floor plan appearing in the folded inserts to show what was done.

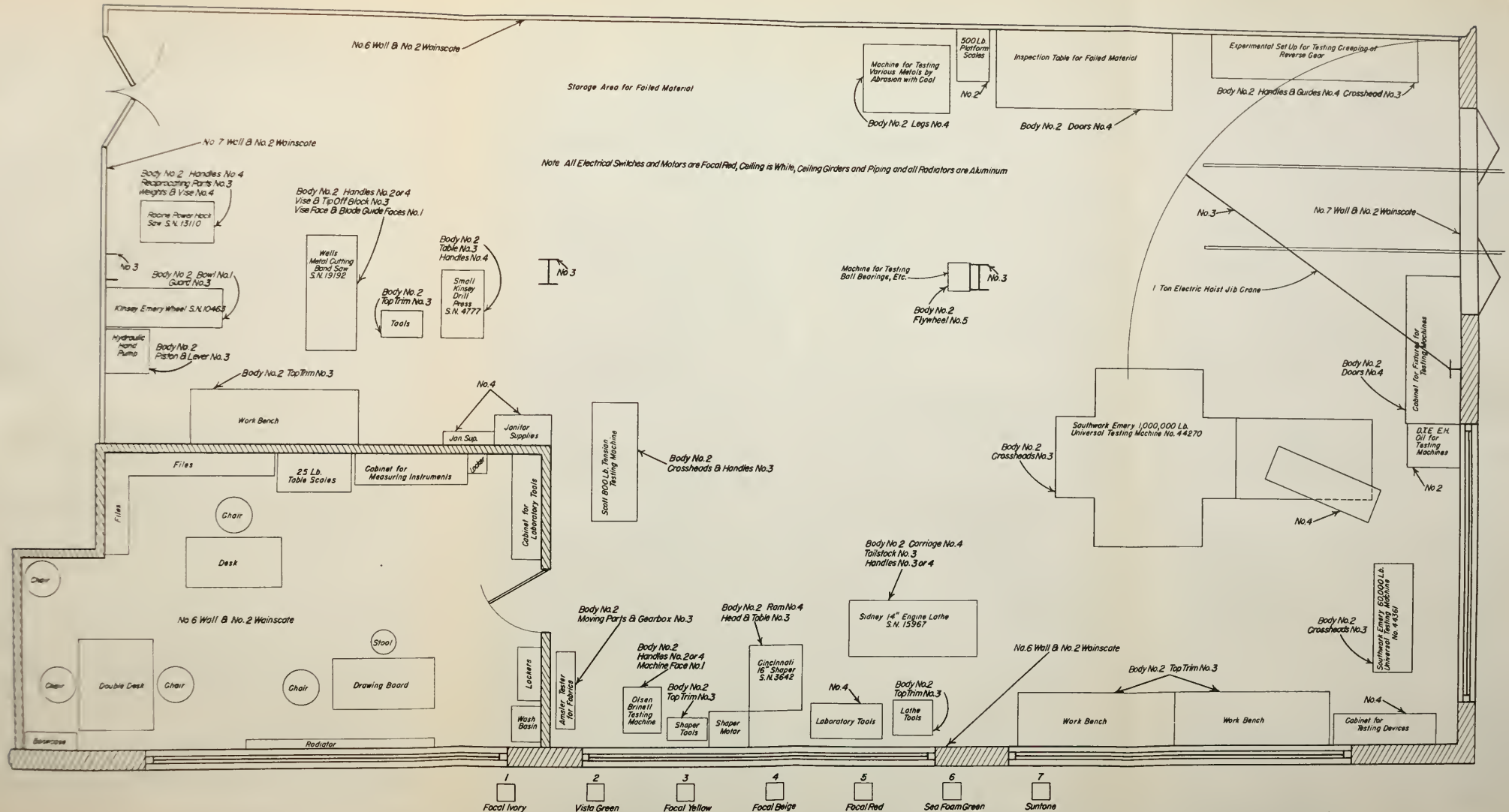
Painting of Old Facilities

In order to do a first class color modernizing job, everything must be arranged in an orderly manner and anything that tends to clutter up the plant and give the impression of disorder should be removed or streamlined as much as possible. Such a procedure is not practical in old railroad facilities as their construction and layout warrants little streamlining. Therefore, all that can be done is to paint machines, walls,

Note All Electrical Switches and Motors are Focal Red, Ceiling is White, Ceiling Girders and Pipes and all Radiators are Aluminum
Miscellaneous Apparatus, including that on benches and tables, is either Vista Green, Focal Beige, or Aluminum

FLOOR PLAN OF CHEMICAL LABORATORY TEST DEPARTMENT
C&O SHOPS HUNTINGTON, W.VA.





FLOOR PLAN OF PHYSICAL LABORATORY TEST DEPARTMENT C&O SHOPS HUNTINGTON, W.VA.

lockers, floors, etc., with colors which will be helpful in brightening up the area to give fair light reflection without glare, and make the critical parts stand out, thus affording as much safety protection as possible.

Conclusion

Color painting has innumerable benefits and plays an important role in increasing production, reducing injuries, giving better working conditions, and uplifting the morale of the workers.

It must be borne in mind that many different color arrangements are recommended for various types of work, and for this reason no rule can be set up which would apply to every problem.

To secure the best color scheme, an expert should be consulted as to proper blending or matching; however, the selection will usually be made by the person or persons in charge of the work who will exercise their individual preferences or tastes.

Proper light reflection values of various colors should be considered when making a selection so that proper light accompanies the color arrangement.

Streamlining is preferred in color painting, however, color painting can be used on old facilities with proper study.

Industrial plants have used this mode of painting for a considerable period of time due to its many advantages; therefore, railroads to parallel the success of other industries, will have to realize that dark, drab and somber painting is obsolete, and must step forward into the color painting field.

Report on Assignment 4

Prefabricated Buildings for Railway Use

J. P. Gallagher (chairman, subcommittee), F. H. Alcott, H. G. Dalton, A. G. Dorland, A. T. Hawk, C. D. Horton, L. P. Kimball, E. S. Lank, J. B. Schaub, R. H. Snyder, J. E. South, O. W. Stephens, A. B. Stone.

The subject of prefabricated buildings relates to any type of building which is produced in sections or panels of floor, wall, ceiling and roof units at the shop or mill and which can be assembled and erected rapidly with a minimum amount of labor at the site.

The prefabrication at the mill or shop of various parts of building construction has been standard practice for many years when such assemblies as sash and doors and their frames, mantels, built-in cupboards and closets and the like are considered. It is only within recent years that serious consideration has been given to mass production of prefabricated buildings which could be readily erected and, after serving their purpose at one location, might easily be taken apart and re-erected speedily, and at a reasonable cost, in another location. The industry is growing but it is still in its infancy, although numerous companies have been organized throughout the country that have definite plans to manufacture prefabricated buildings.

Erected by Others

Most manufacturers furnish the prefabricated sections to form the floor, roof, enclosing walls and interior partitions complete with bolts, etc., for assembly, but it is necessary to employ someone other than the manufacturer to erect the structure. The

Exhibit A.—Color Harmony Suggestions

	Color Harmony No. 1	*Color Harmony No. 2*	*Color Harmony No. 3*	*Color Harmony No. 4*	*Color Harmony No. 5*
Wall	Turquoise	Turquoise	Peach	Peach	Avalon blue
Dado	Medium Turquoise	Silver gray	Beige	Silver gray	Medium blue
Ceiling	White or turquoise tint	White or turquoise tint	White	White	White or avalon blue tint
Machine (a)	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Dark turquoise Floor —Slate Zone mark —White	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Yellow	Medium blue Silhouette —Ivory or Avalon blue Accent —Red and yellow Dado stripe —Dark beige Floor —Graystone Zone mark —Yellow	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Yellow	Silver gray Silhouette —Ivory or medium blue Accent —Red Dado stripe —Dark blue Floor —Slate Zone mark —Yellow
Machine (b)	Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark turquoise Floor —Graystone Zone mark —White	Medium turquoise Silhouette —Ivory or turquoise Accent —Red and yellow Dado stripe —Red Floor —Slate Zone mark —Yellow	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Dark beige Floor —Slate Zone mark —Yellow	Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark beige Floor —Slate Zone mark —Orange	Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark blue Floor —Slate Zone mark —Orange
Machine (c)	Medium turquoise Silhouette —Ivory or turquoise Accent —Red and yellow Dado stripe —Dark turquoise Floor —Slate Zone mark —Yellow	Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark turquoise Floor —Graystone Zone mark —Ivory	Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark beige Floor —Graystone Zone mark —Ivory	Medium turquoise Silhouette —Ivory or turquoise Accent —Red and yellow Dado stripe —Dark turquoise Floor —Slate Zone mark —Yellow	Brown Silhouette —Ivory Accent —Orange Dado stripe —Dark blue Floor —Slate Zone mark —Orange
Machine (d)			Medium turquoise Silhouette —Ivory or turquoise Accent —Red and yellow Dado stripe —Dark turquoise Floor —Graystone Zone mark —Yellow		

Exhibit A.—Color Harmony Suggestions—Continued

	Color Harmony No. 6	*Color Harmony No. 7*	*Color Harmony No 8*	*Color Harmony No. 9*
Wall	Wellington Buff	Wellington Buff	Midland Green	Midland green
Dado	Brown	Medium blue	Medium green	Brown
Ceiling	White or Ivory	White or ivory	White or ivory midland green tint	White or ivory or midland green tint
Machine (a)	Medium Green Silhouette —Ivory or Midland green Accent —Red and yellow Dado stripe —Red Floor —Graystone Zone mark —Yellow	Medium blue Silhouette —Ivory or avalon blue Accent —Yellow Dado stripe —Dark blue Floor —Slate Zone mark —Yellow	Medium green Silhouette —Ivory or midland green Accent —Red and yellow Dado stripe —Dark green Floor —Graystone Zone mark —Yellow	Medium green Silhouette —Ivory or midland green Accent —Red and yellow Dado stripe —Red Floor —Graystone Zone mark —Ivory
Machine (b)	Brown Silhouette —Ivory Accent —Orange Dado stripe —Red Floor —Graystone Zone mark —Ivory	Brown Silhouette —Ivory Accent —Orange Dado stripe —Dark blue Floor —Graystone Zone mark —Ivory	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Dark green Floor —Slate Zone mark —White	Brown Silhouette —Ivory Accent —Orange Dado stripe —Red Floor —Graystone Zone mark —Ivory
Machine (c)	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Ivory	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Dark blue Floor —Slate Zone mark —Ivory	Brown Silhouette —Ivory Accent —Orange Dado stripe —Dark green Floor —Graystone Zone mark —Ivory	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Ivory
Machine (d)	Medium blue Silhouette —Ivory or avalon blue Accent —Yellow Dado stripe —Red Floor —Graystone Zone mark —Yellow		Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark green Floor —Graystone Zone mark —Ivory	

Exhibit A.—Color Harmony Suggestions—Continued

	Color Harmony No. 10	*Color Harmony No. 11*	*Color Harmony No. 12*	*Color Harmony No. 13*
Wall	Ivory	Ivory	Ivory	Ivory
Dado	Brown	Medium blue	Medium turquoise	Medium green
Ceiling	White or ivory	White or ivory or avalon blue	White or ivory or turquoise	White or ivory or midland green tint
Machine (a)	Medium green Silhouette —Ivory or midland green Accent —Red and yellow Dado stripe —Red Floor —Graystone Zone mark —Yellow	Medium blue Silhouette —Ivory or avalon blue Accent —Yellow Dado stripe —Dark blue Floor —Slate Zone mark —Yellow	Medium turquoise Silhouette —Ivory or turquoise Accent —Red and yellow Dado stripe —Dark turquoise Floor —Graystone Zone mark —Yellow	Medium green Silhouette —Ivory or midland green Accent —Red and yellow Dado stripe —Dark green Floor —Graystone Zone mark —Ivory
Machine (b)	Brown Silhouette —Ivory Accent —Orange Dado stripe —Red Floor —Graystone Zone mark —Ivory	Silver gray Silhouette —Ivory or medium blue Accent —Red Dado stripe —Dark blue Floor —Slate Zone mark —Ivory	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Dark turquoise Floor —Slate Zone mark —Ivory	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Dark green Floor —Slate Zone mark —Ivory
Machine (c)	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Ivory		Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark turquoise Floor —Graystone Zone mark —Ivory	Brown Silhouette —Ivory Accent —Orange Dado stripe —Dark green Floor —Graystone Zone mark —Ivory
Machine (d)				Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark green Floor —Graystone Zone mark —Ivory

Exhibit A.—Color Harmony Suggestions—Continued

	Color Harmony No. 14	*Color Harmony No. 15*	*Color Harmony No. 16*	*Color Harmony No. 17*
Wall	Ivory	Jonquil	Jonquil	White
Dado	Silver gray	Brown	Beige	Medium turquoise
Ceiling	White or ivory	White	White	White or turquoise
Machine (a)	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Yellow	Brown Silhouette —Ivory Accent —Orange Dado stripe —Red Floor —Graystone Zone mark —Ivory	Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark beige Floor —Graystone Zone mark —Ivory	White Silhouette —Medium turquoise Accent —Red Dado stripe —Dark turquoise Floor —Slate Zone mark —White
Machine (b)	Beige Silhouette —Ivory Accent —Orange Dado stripe —Dark beige Floor —Graystone Zone mark —Ivory	Medium green Silhouette —Ivory or midland green Accent —Red and yellow Dado stripe —Red Floor —Graystone Zone mark —Ivory or yellow	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Ivory or yellow	Medium turquoise Silhouette —White or turquoise Accent —Red Dado stripe —Red Floor —Slate Zone mark —White
Machine (c)	Medium blue Silhouette —Ivory or avalon blue Accent —Yellow Dado stripe —Dark blue Floor —Slate Zone mark —Yellow	Silver gray Silhouette —Ivory Accent —Red Dado stripe —Red Floor —Slate Zone mark —Yellow	Medium blue Silhouette —Ivory Accent —Yellow Dado stripe —Dark beige Floor —Slate Zone mark —Ivory or yellow	Silver gray Silhouette —White Accent —Red Dado stripe —Dark turquoise Floor —Slate Zone mark —White
Machine (d)	Medium green Silhouette —Ivory or midland green Accent —Red and yellow Dado stripe —Red Floor —Graystone Zone mark —Ivory			

erector installs the foundation, chimney, plumbing and drainage, electric wiring and fixtures, and the heating system. In some instances, the erector furnishes and installs the interior finish including insulation and acoustical treatment. Some producers of the prefabricated house contemplate furnishing the plumbing, kitchen and bathroom units to reduce the amount of extra work in the field that is necessary to produce a complete assembly.

Prefabricated buildings of steel, or the all-metal building, are constructed with lightweight structural steel frames, or shapes fabricated from steel sheets and covered with sheet metal. Some types are covered on the inside of the panels with insulation board which not only affords more comfort within the building, but also adds to its interior appearance and finish. The metal building can be quickly assembled and is a good weathertight structure when erected ready for occupancy. This type has been widely used for many years for automobile storage and garage purposes and has been adopted for many other commercial and industrial building requirements.

Many manufacturers of prefabricated buildings are using wood frames for panel units. The wall and roof panels are covered with plywood or one of the many proprietary wall boards for both exterior and interior finish. Some of these are insulated and, while the cost is somewhat increased, they afford, when erected, the advantages of a permanent structure.

Many Uses on Railroads

The prefabricated building has been used by a number of railroads in recent years for labor camp, bunk house and mess hall installations, small garages for company trucks and cars, flag cabins, section houses, tool sheds and similar facilities. It may be found necessary in many instances to reinforce the walls and floors of the standard types due to occupancies which involve heavy loadings or rough usages.

Some manufacturers have developed their assemblies for two-story structures with limited floor loadings. Such buildings for railroad use should be discouraged because of the promiscuous changes in use after erection, where excessive floor loading, particularly on the second floor, would tend to weaken the structure and develop possible collapse.

Municipal, town and village building codes and ordinances, in many instances, do not permit the erection of prefabricated houses because the materials and construction do not comply with the code requirements. It should also be noted that frame structures are prohibited within the fire limits in practically all communities where building codes have been adopted. The steel or steel frame building generally has the handicap of not complying with codes insofar as the thickness of framing members in tension is concerned. It is of importance to be assured that the prefabricated building selected meets with the minimum fire hazard and safety requirements of building codes before procurement.

Each building problem should be individually studied before prefabricated construction is adopted. The use to which the building is to be assigned is most important. Occupancies introducing heavy loadings and rough operations may develop extraordinary maintenance and repair, which would soon entail expenditures, coupled with the initial cost, far exceeding the cost of a more permanent form of structure.

Report of Committee 3—Ties

JOHN FOLEY, *Chairman,*
M. L. BARDILL
R. S. BELCHER
T. E. BLISS
H. J. BOGARDUS
W. C. BOLIN
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ARTHUR PRICE
W. W. ROHRBAUGH
E. F. SALISBURY
J. G. SUTHERLAND
C. D. TURLEY
A. W. WHITE
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, comprised of recommendations for the revision of the Glossary and Chapter 3, submitted for adoption..... page 124

2. Extent of adherence to specifications.

   No report.

3. Substitutes for wood ties.

   No report.

4. Tie renewals and costs per mile of maintained track.

   Progress report, presented as information..... page 125

5. Cause and control of splitting in railroad ties.

   Progress report, presented as information..... page 126

6. Ways and means for retarding the destruction of ties by mechanical wear.

   Progress report, presented as information..... page 130

7. Reasons for the removal of ties.

   Progress report, presented as information..... page 133

8. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

   No report.

THE COMMITTEE ON TIES,
JOHN FOLEY, *Chairman.*

AREA Bulletin 456, December 1945.

Report on Assignment 1

Revision of Manual

John Foley (chairman, subcommittee), R. E. Butler, F. G. Campbell, W. E. Gardner, B. D. Howe, W. D. Simpson, C. D. Turley.

The following corrections of the Glossary are recommended for the reasons given below.

Delete terms not in Chapter 3, in accordance with the policy established by Board Committee on Manual.

Tie.—Adzed, All-heart, Bored, Boxed-heart, Composite, Concrete, Cull, Doty, Half-moon, Half-round, Halved, Head Block, Heart-and-back, Intermediate, Joint, Pecky, Pole, Quartered, Rectangular, Rifle, Round, Slab, Split, Squared, Squared-pole, Steel, Tapped, Target, Treated, Triangular, Wane, Wing.

Revise the definitions of the following Glossary terms in accordance with current conceptions of them.

Delete reference to Anti-Checking Iron and substitute the following:

Anti-Splitting Iron.—A piece of steel strip, bevelled on both sides at one edge, and bent to a desired shape, for application by driving into the end (cross section) of a tie or timber to control its splitting. *3*

Delete old definitions and substitute new ones as follows:

Dating Nail.—A nail with a head having a raised or depressed number or symbol which is driven into a longitudinal surface of a pile, pole, tie, or timber to identify the year in which the material was treated. *3*

Incising.—Puncturing the longitudinal surfaces of poles, ties, and timbers to assure penetration by a preservative and to relieve surface tension as an aid in the control of checking. *3*

Plug, Tie.—Rectangular sections of wood, shaped somewhat like spikes, for driving into holes from which spikes have been withdrawn. *3*

Tie, Adzed.—A tie which has had the plate-bearing areas of its top made plane and smooth by passage through a machine designed for the purpose. *3*

— Bored.—A tie which has had holes for spikes provided by passage through a machine designed for the purpose. *3*

— Substitute.—A tie of any material other than wood or of wood in combination with any other material. *3*

Include in the Glossary the following definitions of terms in Chapter 3.

Hardwood.—One of the group of trees which have broad leaves. The term has no reference to the hardness of the wood. *3, 7*

Scoremark.—An incision in a longitudinal surface of a hewed tie resulting from a stroke of the axe used in its manufacture. *3*

Softwood.—One of the group of trees which have needle-like or scale-like leaves. The term has no reference to the softness of the wood. *3, 7*

Tie, cross.—The transverse member of the track structure to which the rails are spiked or otherwise fastened to provide proper gage and to cushion, distribute, and transmit the stresses of traffic through the ballast to the roadbed. *3*

Grooved.—A cross tie which has had machine-gouged across its top depressions into which ribs on the bottom of a tie plate may fit. *3*

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1944

Table A

Sheet 1 of 2 sheets

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1944

Road	Cross ties laid in replacement							Total tie applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Average number of cross ties per mile of maintained track	Number of equated gross ton-miles (thousands)	Number of equated gross ton-miles per mile of maintained track (thous.)	New wooden cross tie replacement averages			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood(S) & second-hand(*) renplaced ties							Per cent renewal to all ties in track	Number laid per mile of maintained track	Renewal cost per mile of maintained track	Renewal cost per 1000 equated gross ton-miles
	Number	Average cost	Number	Average cost	Number	Average cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
																	(cents)
NEW ENGLAND REGION:																	
Bangor & Aroostook	51 317	$1.05	38 343	$2.78	89 660	$1.79	-	89 660	822.22	2 361 785	2 872	1 793 521	2 181	3.8	109	$195	8.93
Boston & Maine	109	1.08	210 130	2.20	210 235	2.20	-	210 235	2 935.40	8 659 400	2 950	19 643 698	6 682	2.4	72	157	2.36
Canadian Nat.Linse in New Eng.	2 055	0.86	25 821	1.61	27 876	1.55	-	27 876	248.62	766 873	3 085	671 551	2 701	3.6	112	174	6.45
Canadian Pacific (linse in Me.)	3 313	1.29	10 318	1.84	13 631	1.71	-	13 631	214.93	667 505	3 106	2 402 965	11 180	2.0	63	108	0.97
Canadian Pacific (linse in Vt.)	87	0.90	14 462	1.98	14 549	1.97	-	14 549	124.93	376 243	3 012	641 264	5 133	3.9	116	230	4.47
Central Vermont	-	-	11 514	1.70	11 514	1.70	-	11 514	495.02	1 465 200	2 960	2 844 679	5 747	0.8	23	40	0.69
Maine Central	62 024	1.20	92 392	2.47	154 416	1.96	-	154 416	1 228.43	3 725 500	3 033	4 511 022	3 672	4.1	126	246	6.71
New York Connecting	-	-	3 288	2.88	3 288	2.88	-	3 288	25.90	81 641	3 152	473 887	18 297	4.0	127	365	1.99
New York,New Haven & Hartford	-	-	331 898	2.26	331 898	2.26	-	331 898	3 821.90	11 983 301	3 135	32 467 635	8 495	2.8	87	196	2.31
Rutland	-	-	21 855	1.81	21 855	1.81	-	21 855	487.27	1 514 200	3 108	1 441 477	2 958	1.4	45	81	2.75
Total	118 901	1.13	760 021	2.24	878 922	2.09	-	878 922	10 404.62	31 601 648	3 037	66 861 699	6 426	2.8	84	177	2.75
GREAT LAKES REGION:																	
Ann Arbor	-	-	37 987	2.10	37 987	2.10	-	37 987	402.37	1 220 402	3 033	1 701 855	4 230	3.1	94	198	4.69
Cambria & Indiana	-	-	11 897	2.67	11 897	2.67	-	11 897	56.32	161 800	2 873	175 817	3 122	7.4	211	563	18.04
Delaware & Hudson	163	1.28	211 405	2.55	211 569	2.55	(S) 233	211 802	1 395.26	4 289 274	3 083	17 039 818	12 218	4.9	152	387	3.16
Delaware,Lack.& Western	-	-	181 997	2.34	181 997	2.34	* 10 093	192 090	2 237.64	6 489 406	2 900	20 558 551	9 188	2.8	81	190	2.07
Detroit & Mackinac	25 615	0.88	3 257	2.05	28 872	1.02	-	28 872	277.70	828 425	2 983	244 976	862	3.5	104	106	11.98
Detroit & Toledo Shore Line	-	-	6 532	2.22	6 532	2.22	* 58	6 590	151.16	455 987	3 017	701 588	4 641	1.4	43	96	2.06
Erie	-	-	417 429	2.47	417 429	2.47	-	417 429	4 732.42	13 975 038	2 953	52 553 268	11 105	3.0	88	218	1.97
Grand Trunk Western	-	-	277 275	2.17	277 275	2.17	-	277 275	1 896.55	6 003 326	3 165	10 615 239	5 597	4.6	146	317	5.66
Lehigh & Hudson River	-	-	10 394	2.98	10 394	2.98	-	10 394	113.18	304 247	2 688	1 082 389	9 563	3.4	92	273	2.86
Lehigh & New England	-	-	12 379	2.52	12 379	2.52	-	12 379	258.35	781 510	3 025	1 216 906	4 710	1.6	48	121	2.57
Lehigh Valley	-	-	290 345	2.43	290 345	2.43	-	290 345	2 654.47	7 880 705	2 969	28 498 056	10 736	3.7	109	266	2.48
Monongahela	-	-	30 869	2.41	30 869	2.41	-	30 869	237.98	694 750	2 919	1 328 000	5 580	4.4	130	313	5.61
Montour	5 606	2.11	238	1.84	5 844	2.10	-	5 844	72.39	208 494	2 880	386 483	5 339	2.8	81	169	3.17
New York Central	15 853	1.60	3 127 895	2.35	3 143 748	2.35	* 6 265	3 150 013	20 976.96	64 661 105	3 082	221 070 363	10 539	4.9	150	352	3.34
New York,Chicago & St.Louis	-	-	445 355	2.43	445 355	2.42	-	445 355	2 528.32	7 964 195	3 150	33 124 559	13 101	5.6	176	427	3.26
New York,Ontario & Western	-	-	4 762	2.33	4 762	2.33	* 18 338	23 100	815.91	2 345 151	2 874	3 394 035	4 160	0.2	6	14	0.33
New York,Susq.& Western	-	-	9 870	1.69	9 870	1.69	-	9 870	214.70	625 408	2 913	432 404	2 014	1.6	46	78	3.65
Pere Marquette	-	-	393 583	1.95	393 583	1.95	-	393 583	2 582.79	7 700 161	2 981	16 964 444	6 568	5.1	152	297	4.52
Pittsburgh & Lake Erie	-	-	87 380	2.38	87 380	2.38	-	87 380	868.54	2 603 684	2 996	5 647 645	6 499	3.4	101	239	3.68
Pittsburg & Shawmut	121	1.42	23 691	2.84	23 812	2.84	* 607	24 419	115.32	326 660	2 833	340 963	2 957	7.3	206	586	19.80
Pittsburgh & West Virginia	-	-	22 454	2.75	22 454	2.75	-	22 454	182.60	555 293	3 041	1 433 859	7 852	4.0	123	338	4.30
Pittsburg,Shawmut & Northern	18 940	1.21	4 663	2.34	23 603	1.43	-	23 603	219.21	643 828	2 937	327 157	1 492	3.7	108	254	10.33
Wabash	-	-	372 812	2.00	372 812	2.00	-	372 812	3 160.97	9 851 453	3 117	30 535 851	9 660	3.8	118	236	2.44
Total	66 298	1.08	5 984 470	2.32	6 050 768	2.31	35 594	6 086 362	46 147.51	140 570 302	3 046	449 374 208	9 738	4.3	131	303	3.11
CENTRAL EASTERN REGION:																	
Akron,Canton & Youngstown	46 696	1.82	-	-	46 696	1.82	-	46 696	214.32	616 809	2 878	938 935	4 381	7.6	218	396	9.05
Baltimore & Ohio	-	-	1 974 438	2.21	1 974 438	2.21	-	1 974 438	10 328.74	29 456 707	2 852	115 814 186	11 213	6.7	191	422	3.76
Bessemer & Lake Erie	-	-	19 479	2.85	19 479	2.85	-	19 479	487.62	1 516 660	3 110	5 099 215	10 457	1.3	40	114	1.09
Central R.R.of New Jersey	-	-	148 766	2.40	148 766	2.40	-	148 766	1 426.90	4 010 976	2 811	12 145 557	8 512	3.7	104	250	2.94
Chicago & Eastern Illinois	-	-	170 088	1.72	170 088	1.72	-	170 088	1 330.96	4 127 174	3 101	12 434 228	9 342	4.1	128	220	2.36
Chicago & Illinois Midland	-	-	25 188	2.88	25 188	2.88	-	25 188	168.33	507 062	3 012	615 219	3 655	5.0	150	431	11.80
Chicago,Indpls.& Louisville	4	1.26	49 157	1.59	49 161	1.59	-	49 161	740.27	2 298 318	3 105	3 542 862	4 786	2.1	66	105	2.20
Detroit,Toledo & Ironton	2 807	0.44	25 693	1.75	28 500	1.62	-	28 500	600.29	1 728 835	2 880	1 970 618	3 283	1.6	47	77	2.34
Elgin,Joliet & Eastern	-	-	126 644	1.98	126 644	1.98	* 532	130 176	865.79	2 669 995	3 084	4 365 415	5 042	4.7	146	290	5.76
Illinois Terminal Co.	3 793	1.25	51 046	1.59	54 839	1.57	* 666	55 505	628.70	1 886 100	3 000	1 574 313	2 504	2.9	87	137	5.47
Long Island	-	-	167 831	2.87	167 831	2.87	-	167 831	797.41	2 274 517	2 852	4 856 883	6 091	7.4	210	604	9.92
Missouri-Illinois	-	-	46 678	1.88	46 678	1.88	-	46 678	213.14	668 000	3 134	452 892	2 125	7.0	219	411	19.35
Pennsylvania	-	-	2 161 999	2.30	2 161 999	2.30	-	2 161 999	21 370.17	60 991 156	2 854	280 960 451	13 147	3.5	101	233	2.77
Penna.-Reading Seashore Lines	-	-	52 471	2.62	52 471	2.62	-	52 471	635.44	1 724 715	2 714	2 012 353	3 199	3.0	83	218	6.76
Reading Co.	-	-	425 713	2.37	425 713	2.37	-	425 713	2 927.90	9 088 329	3 104	25 207 530	8 609	4.7	145	345	4.01
Staten Island Rapid Transit	-	-	4 905	2.52	4 905	2.52	-	4 905	79.98	217 846	2 724	179 295	2 242	2.3	61	155	6.90
Western Maryland	4 100	1.52	120 725	2.30	124 825	2.27	-	124 825	1 145.42	3 301 149	2 882	9 741 234	8 505	3.8	109	248	2.91
Wheeling & Lake Erie	414	1.40	78 545	2.28	78 959	2.28	* 907	79 866	839.65	2 526 840	3 009	5 546 404	6 606	3.1	94	214	3.24
Total	57 814	1.69	5 649 166	2.26	5 706 980	2.25	5 105	5 712 085	44 800.99	129 611 192	2 893	487 677 810	10 885	4.4	127	287	2.63
POCAHONTAS REGION:																	
Chesapeake & Ohio	-	-	503 058	2.01	503 058	2.01	-	503 058	5 035.42	15 484 935	3 075	74 028 804	14 702	3.2	100	200	1.36
Norfolk & Western	-	-	283 063	1.86	283 063	1.86	* 4 093	287 156	4 269.24	13 234 644	3 100	54 728 692	12 819	2.1	66	124	0.96
Richmond,Fred.& Potomac	-	-	72 820	2.19	72 820	2.19	* 649	73 469	398.63	1 140 000	2 860	8 878 546	22 273	6.4	183	400	1.79
Virginian	-	-	97 190	1.73	97 190	1.73	* 1 312	98 502	904.43	2 781 620	3 076	9 691 288	10 715	3.5	107	186	1.74
Total	-	-	956 131	1.95	956 131	1.95	6 054	962 185	10 607.72	32 641 199	3 077	147 327 330	13 889	2.9	90	176	1.27
SOUTHERN REGION:																	
Alabama Great Southern	1 371	1.70	71 307	2.41	72 678	2.40	-	72 678	552.44	1 667 140	3 018	7 263 783	13 149	4.4	132	316	2.40
Atlanta & West Point	11 974	1.83	16 171	2.17	28 145	2.03	-	28 145	139.91	431 859	3 087	1 392 140	9 950	6.5	201	408	4.10
Atlanta,Birmingham & Coast	20 727	1.41	147 216	2.10	167 943	2.02	-	167 943	791.13	2 288 320	2 892	2 743 334	3 468	7.3	212	428	12.34
Atlantic Coast Line	7 164	1.40	1 173 263	1.99	1 180 427	1.98	-	1 180 427	6 626.56	19 397 603	2 927	45 917 661	6 929	6.1	178	354	5.10
Central of Georgia	1 066	1.98	129 883	1.64	130 954	1.64	-	130 954	2 257.33	6 678 438	2 959	12 068 130	5 346	5.0	147	241	4.32
Charleston & Western Carolina	15 324	1.72	62 186	2.06	77 510	2.00	-	77 510	425.51	1 229 973	2 891	1 356 225	3 187	6.3	182	364	11.42
Cin.,New Orleans & Tex.Pac.	86	1.31	43 196	2.55	43 282	2.55	-	43 282	771.36	2 274 700	2 949	12 036 570	15 604	1.9	56	143	0.92
Clinchfield	29 027	1.31	22 754	2.01	51 781	1.62	-	51 781	397.20	1 207 472	3 040	4 522 300	11 385	4.3	130	211	1.85
Columbus & Greenville	763	1.04	33 300	2.09	34 063	2.06	-	34 063	204.03	646 367	3 168	299 469	1 468	5.3	167	345	23.40
Florida East Coast	36 493	1.61	192 152	2.33	228 645	2.21	-	228 645	1 252.64	3 597 443	2 872	8 366 338	6 679	6.4	183	414	6.20
Georgia	73 755	1.85	15 149	2.33	91 944	1.94	-	91 944	433.93	1 332 301	3 070	2 796 413	6 444	6.9	212	412	6.39
Georgia & Florida	144 796	1.04	-	-	144 796	1.04	-	144 796	456.33	1 232 091	2 700	692 172	1 517	11.8	317	331	21.84
Georgia,Southern & Florida	48 862	1.54	3 726	2.19	52 588	1.59	-	52 588	463.85	1 459 954	3 147	2 018 507	4 395	3.6	113	180	4.10
Gulf & Ship Island	-	-	72 994	1.77	72 994	1.77	-	72 994	303.04	937 763	3 095	801 522	2 645	7.8	241	425	16.68
Gulf,Mobile & Ohio	36 600	1.32	558 525	2.08	595 125	2.03	* 1 636	596 763	2 027.18	6 422 078	3 166	11 083 124	5 467	9.3	294	596	10.90
Illinois Central	1 972	1.65	1 628 015	1.87	1 629 987	1.87	(S)1 688	1 631 675	7 498.80	22 865 429	3 049	72 944 496	9 727	7.1	217	407	4.19
Louisville & Nashville	988	0.89	868 397	1.90	869 385	1.90	-	869 385	6 705.47	19 199 627	2 863	60 892 938	9 081	4.5	130	246	2.71
Mississippi Central	43	0.95	21 575	2.07	21 618	2.07	-	21 618	176.87	557 943	3 155	457 022	2 584	3.9	122	232	9.77
Nashville,Chatt.& St.Louis	267	1.11	305 815	2.04	306 082	2.04	-	306 082	1 469.40	4 022 857	2 737	11 367 610	7 738	7.6	208	425	5.49
New Orleans & Northeastern	1 347	1.47	58 248	2.52	60 095	2.50	-	60 095	289.71	845 470	2 918	4 003 668	13 820	7.1	207	519	3.75
Norfolk Southern	145 656	1.19	86 976	2.32	232 632	1.61	-	232 632	853.98	2 493 451	2 920	2 113 228	2 475	9.3	272	439	17.15
Seaboard Air Line	124 644	1.62	974 649	2.13	1 099 293	2.07	-	1 099 293	5 302.49	16 045 808	3 026	40 895 562	7 713	6.9	207	430	5.58
Southern Ry.	97 312	1.62	1 224 191	2.13	1 321 503	2.26	-	1 321 503	8 608.37	26 668 088	3 098	68 157 000	7 918	5.0	154	350	4.42
Tennessee Central	18 829	1.23	33 284	2.26	51 913	1.89	-	51 913	342.70	1 037 817	3 028	1 330 102	3 298	5.0	151	287	8.69
Western Ry.of Alabama	35 388	1.84	10 561	2.18	45 949	1.92	-	45 949	183.63	559 557	3 047	1 481 513	8 068	8.2	250	480	5.95
Yazoo & Mississippi Valley	1 076	1.27	664 730	1.90	665 806	1.90	-	665 806	2 028.14	6 191 263	3 053	9 447 757	4 658	10.8	328	625	13.41
Total	855 330	1.44	8 622 005	2.04	9 477 335	1.98	3 326	9 480 661	50 562.40	151 290 930	2 992	386 268 584	7 639	6.3	187	372	4.87

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1944

Road	Cross ties laid in replacement								Miles of main-tained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Average number of cross ties per mile of main-tained track	Number of equated gross ton-miles a (thousands)	Number of equated gross ton-miles per mile of main-tained track (thous.)	New wooden cross tie replacement averages			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood (S) & second-hand(*) reapplied ties	Total ties applied						Per cent renewal to all ties in track	Number laid per mile of main-tained track	Sensual cost per mile of main-tained track	Renewal cost per 1000 equated gross ton-miles
	Number	Aver-age cost	Number	Aver-age cost	Number	Aver-age cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NORTHWESTERN REGION:																	(cents)
Chicago & North Western	61 307	$0.91	1 149 402	$1.82	1 210 509	$1.78	-	1 210 509	11 227.30	33 256 250	2 962	51 235 251	4 563	3.6	108	192	4.20
Chicago Great Western	127 061	1.49	210 369	2.14	337 430	1.90	-	337 430	1 877.02	5 566 894	2 966	11 433 326	6 091	6.1	180	341	5.60
Chicago, Milwaukee, St. Paul & Pac.	384 458	0.92	1 803 692	1.90	2 188 150	1.73	-	2 188 150	13 564.69	41 956 697	3 093	71 257 870	5 253	5.2	161	279	5.31
Chicago, St. Paul, Minpls & Omaha	4 364	1.07	281 114	1.95	285 478	1.93	-	285 478	2 152.34	6 381 447	2 965	8 244 329	3 830	4.5	133	256	6.69
Duluth, Missabe & Iron Range	7 516	1.23	89 710	2.15	97 226	2.08	(S) 145	97 371	1 093.01	3 256 052	2 979	7 413 738	6 781	3.0	89	185	2.72
Duluth, South Shore & Atlantic	30 050	1.01	46 650	1.85	76 700	1.52	-	76 700	519.79	1 539 666	2 962	1 201 262	2 311	5.0	148	224	9.69
Elgin, Joliet & Eastern	13 499	1.33	57 235	2.16	70 734	2.00	-	70 734	207.00	608 178	2 938	969 809	4 685	11.6	342	682	14.56
Great Northern	18 346	0.89	1 713 238	1.96	1 731 584	1.95	* 21 911	1 753 495	10 233.16	31 603 897	3 088	63 702 716	6 225	5.5	169	330	5.31
Green Bay & Western	36 012	1.25	74 818	2.40	110 830	2.03	-	110 830	283.05	815 184	2 880	832 134	2 940	13.6	392	793	26.98
Lake Superior & Ishpeming	18 244	1.17	13 175	2.18	31 419	1.59	-	31 419	233.89	701 670	3 000	199 879	854	4.5	134	213	25.00
Minneapolis & St. Louis	66 925	1.20	144 721	1.84	211 646	1.64	-	211 646	1 563.25	4 721 787	3 020	4 061 861	2 596	4.3	135	221	8.52
Minneapolis, St. Paul & S.S.Marie	75 004	1.11	336 778	1.88	411 782	1.74	-	411 782	4 888.73	14 418 132	2 949	16 275 143	3 329	2.9	84	147	4.41
Northern Pacific	15 137	1.07	963 075	1.63	978 212	1.62	-	978 212	9 178.18	26 648 694	2 903	53 993 007	5 883	3.7	107	172	2.93
Spokane International	77 160	1.16	-	-	77 160	1.16	-	77 160	177.22	525 070	2 906	379 061	2 139	15.0	435	506	23.66
Spokane, Portland & Seattle	17 436	0.81	536 248	1.93	553 684	1.89	-	553 684	1 125.38	3 425 922	3 044	7 484 052	6 650	16.2	492	932	14.01
Total	952 319	1.08	7 420 225	1.89	8 372 544	1.79	22 056	8 394 600	58 324.01	175 415 540	3 008	298 683 238	5 121	4.8	144	258	5.03
CENTRAL WESTERN REGION:																	
Alton	124 548	1.46	148 565	2.46	273 113	2.00	* 1 755	274 868	1 507.48	4 551 175	3 019	10 646 929	7 063	6.0	182	363	5.14
Atchison, Topeka & Santa Fe	2 764	1.96	1 473 505	1.50	1 476 269	1.50	-	1 476 269	19 022.97	57 772 760	3 037	173 676 869	9 130	2.6	78	116	1.27
Chicago, Burlington & Quincy	-	-	2 184 373	1.84	2 184 373	1.84	* 57 922	2 242 295	11 972.12	36 969 906	3 088	73 910 622	6 174	5.9	182	336	5.44
Chicago, Rock Island & Pacific	-	-	1 580 059	2.01	1 580 059	2.01	-	1 580 059	9 583.63	28 645 417	2 989	60 052 967	6 266	5.5	165	331	5.28
Colorado & Southern	-	-	81 823	1.90	81 823	1.90	* 2 772	84 595	826.33	2 478 990	3 000	5 535 378	6 699	3.3	99	188	2.81
Colorado & Wyoming	-	-	7 472	2.82	7 472	2.82	-	7 472	108.35	312 246	2 882	29 577	273	2.4	69	195	71.35
Denver & Rio Grande Western	2 521	0.69	122 517	1.88	125 038	1.86	* 47 934	172 972	3 129.88	9 756 147	3 117	22 530 422	7 198	1.3	40	74	1.01
Denver & Salt Lake	-	-	73 377	2.24	73 377	2.24	-	73 377	320.24	969 278	3 027	1 013 979	3 166	7.6	229	691	21.81
Fort Worth & Denver City	-	-	111 134	1.99	111 134	1.99	* 8 242	119 376	946.51	3 846 230	4 064	5 090 085	5 378	2.9	117	174	3.23
Northwestern Pacific	118 977	1.73	5 486	1.92	124 463	1.74	-	124 463	419.04	1 215 844	2 901	1 141 708	2 725	10.2	297	516	18.94
Southern Pacific Co.- Pac.Lines	193 104	1.21	1 583 627	1.77	1 776 731	1.71	* 213	1 776 944	11 872.41	34 798 581	3 000	139 651 217	11 763	4.8	150	258	2.17
Toledo, Peoria & Western	-	-	16 848	1.77	16 848	1.77	-	16 848	278.00	880 704	3 168	1 220 501	4 390	1.9	61	107	2.45
Union Pacific	10 796	1.20	2 091 880	1.54	2 102 676	1.54	-	2 102 676	13 118.98	37 066 198	2 825	151 571 715	11 554	5.7	160	246	2.13
Utah	765	1.24	2 960	2.62	3 725	2.34	* 883	4 608	71.49	203 042	2 840	324 496	4 539	1.8	52	122	2.68
Western Pacific	288 702	1.42	154 980	2.41	443 682	1.76	* 226	443 908	1 514.74	4 524 990	2 987	16 868 691	11 136	9.8	293	517	4.64
Total	742 177	1.42	9 638 606	1.76	10 380 783	1.74	119 947	10 500 730	74 692.17	225 991 508	3 026	663 265 156	8 880	4.6	139	242	2.72
SOUTHWESTERN REGION:																	
Beaumont, Sour Lake & Western	-	-	37 758	1.90	37 758	1.90	-	37 758	148.15	441 000	2 977	2 703 815	18 251	8.6	255	484	2.65
Burlington-Rock Island	-	-	16 961	1.22	16 961	1.22	-	16 961	177.77	556 420	3 130	862 459	4 852	3.0	95	117	2.40
International-Great Northern	-	-	144 637	1.86	144 637	1.86	-	144 637	1 420.56	4 257 400	2 997	8 949 733	6 300	3.4	102	190	3.01
Kansas City Southern	411	1.04	314 907	1.75	315 318	1.75	-	315 318	1 256.70	3 979 654	3 167	13 098 331	10 423	7.9	251	439	4.21
Kansas, Oklahoma & Gulf	-	-	21 306	1.72	21 306	1.72	-	21 306	352.96	1 044 761	2 960	1 185 943	3 360	2.0	60	104	3.09
Louisiana & Arkansas	133	1.35	417 725	1.86	417 858	1.86	-	417 858	931.98	3 042 969	3 265	4 417 208	4 740	13.7	448	832	17.56
Midland Valley	30	0.20	24 255	1.46	24 285	1.46	-	24 285	159.53	1 064 209	2 960	418 554	2 164	2.3	68	99	8.48
Missouri & Arkansas	37 452	1.11	100 244	1.63	137 696	1.49	-	137 696	358.60	1 115 442	3 111	662 544	1 848	12.3	384	573	30.99
Missouri-Kansas-Texas Lines	-	-	1 271 802	1.94	1 271 802	1.94	-	1 271 802	3 910.82	12 304 600	3 146	27 641 421	7 068	10.3	325	630	8.91
Missouri Pacific	22 246	1.09	823 441	1.70	845 687	1.69	-	845 687	8 920.55	27 527 075	3 086	76 983 225	8 630	3.1	95	166	2.85
New Orleans, Texas & Mexico	-	-	37 820	2.00	37 820	2.00	* 11 527	49 347	224.73	687 500	3 059	1 964 098	8 740	5.5	168	336	3.85
Oklahoma City-Ada-Atoka	2 075	0.17	37 746	0.90	39 821	0.87	-	39 821	138.89	400 003	2 880	174 043	1 253	10.0	287	248	19.80
St. Louis, Brownsville & Mexico	128	0.82	140 968	1.90	141 096	1.90	* 3 735	144 831	757.55	2 292 300	3 026	4 977 217	6 570	6.2	186	354	5.39
St. Louis-San Francisco	76 842	1.14	746 257	1.62	823 099	1.58	-	823 099	6 234.67	19 624 345	3 148	37 448 633	6 007	4.2	132	208	3.46
St. Louis, San Fran. & Texas	1 281	1.15	12 663	1.57	13 944	1.53	-	13 944	153.66	480 058	3 124	707 211	4 602	2.9	91	139	3.02
St. Louis Southwestern Lines	-	-	383 864	1.85	383 864	1.85	* 872	384 736	1 865.32	5 867 486	3 146	19 439 912	10 422	6.5	206	380	3.65
San Antonio, Uvalde & Gulf	-	-	61 819	1.13	61 819	1.13	* 3 630	65 449	359.77	1 037 600	2 884	853 625	2 373	6.0	172	194	8.17
Texas & New Orleans	1 764	0.92	708 791	1.57	710 555	1.57	-	710 555	5 563.65	15 172 358	2 727	39 164 331	7 039	4.7	128	201	2.85
Texas & Pacific	-	-	552 997	1.77	552 997	1.77	-	552 997	2 383.54	6 963 500	2 921	21 665 194	9 090	7.9	232	411	4.52
Texas Mexican	636	0.25	20 534	1.84	21 170	1.79	-	21 170	203.03	643 199	3 168	216 335	1 065	3.3	104	187	17.56
Total	142 998	1.10	5 876 495	1.75	6 019 493	1.74	19 764	6 039 257	35 722.43	108 501 879	3 037	263 533 812	7 377	5.5	169	293	3.97
Grand total, United States	2 935 837	1.28	44 907 119	1.98	47 842 956	1.94	211 846	48 054 802	331 261.85	995 624 198	3 006	2 762 991 637	8 341	4.8	144	280	3.36
CANADIAN ROADS:																	
Canadian National	2 133 498	1.03	2 308 772	1.58	4 442 270	1.32	-	4 442 270	26 877.00	78 784 801	2 931	115 214 440	4 287	5.6	165	217	5.07
Canadian Pacific	1 643 663	1.10	1 422 474	1.80	3 066 137	1.42	-	3 066 137	21 080.00	60 708 425	2 880	100 610 559	4 773	5.2	145	207	4.34
Temiskaming & Northern Ontario	129 917	0.90	-	-	129 917	0.90	-	129 917	679.70	1 970 550	2 899	1 863 258	2 741	6.6	191	172	6.28

a Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.

Note: "Average cost" as shown in columns 3, 5 and 7, represents storekeepers' average cost of ties charged out and used. They are not the actual costs or the prices paid for ties purchased during the period.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.
from Annual Reports of Class I Railways to the Interstate Commerce Commission.
June 30, 1945

Table B

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Table 8

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1940 to 1944, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wooden cross tie renewals per mile of maintained track						Aggregate cost of new wooden cross tie renewals per mile of maintained track						Per cent new wooden cross tie renewals to all ties in tracks					
	1940	1941	1942	1943	1944	5 year average	1940	1941	1942	1943	1944	5 year average	1940	1941	1942	1943	1944	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	175	146	158	114	109	140	$113	$92	$99	$84	$195	$117	6.1	5.1	5.5	4.0	3.8	4.9
Boston & Maine	97	122	106	66	72	93	150	190	186	131	157	163	3.3	4.1	3.6	2.2	2.4	3.1
Canadian Net.Lines in New Eng.	152	186	127	80	112	131	164	200	154	104	174	159	4.9	6.0	4.1	2.6	3.6	4.2
Canadian Pacific (lines in Me.)	56	46	60	71	63	59	67	63	98	91	108	85	1.8	1.5	2.0	2.4	2.0	1.9
Canadian Pacific (lines in Vt.)	62	87	99	74	116	88	87	131	141	96	230	133	2.1	2.9	3.3	2.5	3.9	2.9
Central Vermont	84	69	53	29	23	52	104	95	77	44	40	72	2.9	2.4	1.8	1.0	0.8	1.8
Maine Central	161	153	142	119	126	140	185	208	215	208	246	212	5.3	5.0	4.7	3.9	4.1	4.6
New York Connecting	377	317	223	154	127	240	672	571	559	430	365	519	12.0	10.1	7.1	4.9	4.0	7.6
New York,New Haven & Hartford	53	64	66	67	87	67	54	68	118	146	196	116	1.7	2.1	2.1	2.1	2.8	2.2
Rutland	46	44	46	45	45	45	57	63	67	63	81	66	1.5	1.4	1.5	1.5	1.4	1.5
Total	92	100	94	74	84	89	108	127	145	133	177	138	3.1	3.3	3.1	2.4	2.8	2.9
GREAT LAKES REGION:																		
Ann Arbor	90	94	93	90	94	92	132	141	145	154	198	154	3.0	3.1	3.1	3.0	3.1	3.1
Cambria & Indiana	350	324	235	326	211	289	651	594	553	842	563	641	12.9	11.9	8.6	11.9	7.4	10.5
Delaware & Hudson	116	169	157	109	152	141	215	264	246	239	387	270	3.8	5.5	5.1	3.5	4.9	4.6
Delaware,Lackawanna & Western	54	82	99	65	81	76	89	134	191	145	190	150	1.9	2.8	3.4	2.2	2.8	2.6
Detroit & Mackinac	115	109	92	109	104	106	69	69	67	98	106	82	3.8	3.6	3.1	3.7	3.5	3.5
Detroit & Toledo Shore Line	119	109	140	92	43	101	213	195	265	205	96	195	4.0	3.6	4.7	3.0	1.4	3.3
Erie	83	85	86	79	88	84	118	124	140	158	218	152	2.8	2.9	2.9	2.6	3.0	2.8
Grand Trunk Western	156	181	160	148	146	158	243	274	258	275	317	273	4.9	5.7	5.1	4.7	4.6	5.0
Lehigh & Hudson River	74	96	35	164	92	92	163	227	81	458	273	240	2.7	3.6	1.3	6.1	3.4	3.4
Lehigh & New England	62	57	53	54	48	55	105	103	114	113	121	111	2.1	1.9	1.8	1.8	1.6	1.8
Lehigh Valley	57	63	60	74	109	73	100	108	120	166	266	152	1.9	2.1	2.0	2.5	3.7	2.4
Monongahela	180	149	195	147	130	160	294	241	351	337	313	307	6.2	5.2	6.7	5.0	4.4	5.5
Montour	96	86	88	70	81	84	205	196	210	129	169	182	3.3	3.0	3.0	2.4	2.8	2.9
New York Central	99	123	131	131	150	127	148	191	238	268	352	239	3.1	4.0	4.3	4.2	4.9	4.1
New York,Chicago & St.Louis	118	138	143	132	176	141	172	212	262	265	427	268	3.7	4.4	4.5	4.2	5.6	4.5
New York,Ontario & Western	-	-	12	8	6	5	-	-	30	18	14	12	-	-	0.4	0.3	0.2	0.2
New York,Susquehanna & Western	69	63	58	54	46	58	42	35	47	62	78	53	2.4	2.2	2.0	1.8	1.6	2.0
Pere Marquette	174	170	168	169	152	167	281	264	260	272	297	275	5.8	5.6	5.6	5.6	5.1	5.5
Pittsburgh & Lake Erie	93	122	114	98	101	106	172	228	236	239	239	223	3.1	4.1	3.8	3.3	3.4	3.5
Pittsburg & Shawmut	255	156	197	181	206	199	369	277	448	454	586	427	9.1	5.6	7.0	6.4	7.3	7.1
Pittsburgh & West Virginia	310	292	252	171	123	230	628	591	507	382	338	489	10.2	9.6	8.3	5.6	4.0	7.5
Pittsburg,Shawmut & Northern	162	174	72	123	108	128	162	176	82	175	154	150	5.5	5.9	2.5	4.2	3.7	4.4
Wabash	146	151	140	126	118	136	225	238	225	211	236	227	4.7	4.8	4.5	4.1	3.8	4.4
Total	104	121	123	118	131	119	160	188	216	233	303	220	3.4	4.0	4.0	3.8	4.3	3.9
CENTRAL EASTERN REGION:																		
Akron,Canton & Youngstown	234	242	250	226	218	234	323	344	412	406	396	376	7.8	8.4	8.7	7.8	7.6	8.1
Baltimore & Ohio	113	154	151	200	191	162	165	240	268	428	422	305	4.0	5.4	5.3	7.0	6.7	5.7
Bessemer & Lake Erie	148	121	83	57	40	90	322	257	181	147	114	204	4.8	4.0	2.7	1.8	1.3	2.9
Central R.R.of New Jersey	90	116	83	77	104	94	154	199	165	175	230	189	3.2	4.1	2.9	2.7	3.7	3.3
Chicago & Eastern Illinois	107	117	109	118	128	116	228	237	238	208	220	166	3.7	3.8	3.5	3.8	4.1	3.8
Chicago & Illinois Midland	58	85	125	156	150	115	97	173	323	410	431	285	1.9	2.8	4.1	5.2	5.0	3.8
Chicago,Indplo.& Louisville	98	89	79	58	66	78	112	103	95	76	105	98	3.2	2.9	2.6	1.9	2.1	2.5
Detroit,Toledo & Ironton	82	65	58	55	47	61	112	93	79	80	77	88	2.8	2.3	2.0	1.9	1.6	2.1
Elgin,Joliet & Eastern	182	201	149	83	146	152	284	312	234	153	290	255	5.9	6.5	4.8	2.7	4.7	4.9
Illinois Terminal	102	104	85	80	87	92	127	126	110	109	137	122	3.4	3.5	2.8	2.7	2.9	3.1
Long Island	61	70	93	146	210	116	102	130	200	356	604	278	2.1	2.5	3.3	5.1	7.4	4.2
Missouri-Illinois	273	211	248	211	219	232	187	254	322	335	411	302	8.8	6.7	7.9	6.7	7.4	7.4
Pennsylvania	84	108	113	97	101	100	136	168	185	180	233	180	3.0	3.8	3.9	3.4	3.5	3.5
Penna.-Reading Seashore Lines	127	85	78	74	83	89	237	163	190	185	216	198	4.9	3.1	2.9	2.7	3.0	3.3
Reading Co.	58	76	88	104	145	94	105	139	176	227	345	198	2.1	2.8	3.2	3.8	4.7	3.3
Staten Island Rapid Transit	96	48	66	70	61	68	56	88	142	160	155	120	3.5	1.7	2.4	2.6	2.3	2.5
Western Maryland	179	141	120	102	109	130	265	226	207	202	248	230	6.3	4.9	4.2	3.5	3.8	4.3
Wheeling & Lake Erie	172	233	204	121	94	165	251	341	319	211	214	267	5.7	7.8	6.8	4.0	3.1	5.5
Total	99	121	119	121	127	117	152	189	204	243	287	215	3.5	4.2	4.2	4.2	4.4	4.1
POCAHONTAS REGION:																		
Chesapeake & Ohio	76	91	83	96	100	89	97	123	120	155	200	139	2.5	3.0	2.7	3.1	3.2	2.9
Norfolk & Western	41	44	45	69	66	53	55	60	66	112	124	83	1.3	1.4	1.4	2.2	2.1	1.7
Richmond,Fred.& Potomac	357	389	402	294	183	325	605	663	711	588	400	593	12.5	13.6	14.1	10.3	6.4	11.4
Virginian	143	111	97	101	107	112	194	150	137	166	186	167	4.6	3.6	3.1	3.3	3.5	3.6
Total	77	84	80	93	90	85	106	119	121	155	176	135	2.5	2.7	2.6	3.0	2.9	2.7
SOUTHERN REGION:																		
Alabama Great Southern	87	79	86	97	132	96	154	141	156	207	316	195	2.8	2.6	2.8	3.2	4.4	3.2
Atlanta & West Point	153	247	250	202	201	211	188	308	368	363	408	327	5.0	8.0	8.1	6.5	6.5	6.8
Atlanta,Birmingham & Coast	154	147	144	144	212	160	152	164	197	249	428	238	5.3	5.1	5.0	5.0	7.3	5.5
Atlantic Coast Line	120	117	153	176	178	149	110	123	228	330	354	229	4.1	4.0	5.3	6.0	6.1	5.1
Central of Georgia	156	160	167	147	147	155	158	173	188	214	241	195	5.3	5.4	5.6	5.0	5.0	5.2
Charleston & Western Carolina	137	131	161	184	182	159	149	143	224	278	364	232	4.8	4.5	5.6	6.4	6.3	5.5
Cincinnati,New Orleans & Tex.Pac.	65	61	48	44	56	55	115	108	88	85	143	108	2.1	2.0	1.6	1.4	1.9	1.8
Clinchfield	246	231	193	172	130	194	250	261	254	296	211	254	8.1	7.6	6.3	5.7	4.3	6.4
Columbus & Greenville	126	143	170	179	167	157	145	171	224	318	345	241	4.0	4.5	5.4	5.7	5.1	5.0
Florida East Coast	199	156	177	154	183	174	209	183	309	293	414	282	6.9	5.5	6.2	5.3	6.4	6.1
Georgia R.R.	154	235	236	270	212	221	173	272	326	392	412	315	5.0	7.7	7.7	8.8	6.9	7.2
Georgia & Florida	202	205	307	285	317	263	127	138	261	253	331	222	7.5	7.6	11.4	10.5	11.8	9.8
Georgia,Southern & Florida	124	127	128	141	113	127	134	142	142	207	180	165	4.0	4.1	4.1	4.5	3.6	4.1
Gulf & Ship Island	223	237	220	247	241	234	238	247	269	383	425	312	7.2	7.7	7.1	8.0	7.8	7.6
Gulf,Mobile & Ohio	312	326	337	277	294	309	300	341	499	599	586	447	9.8	10.3	10.6	8.7	9.3	9.7
Illinois Central	185	194	195	160	217	194	205	213	254	293	407	274	6.1	6.3	6.4	5.9	7.1	6.4
Louisville & Nashville	123	137	164	189	130	149	176	198	243	306	246	234	4.3	4.8	5.7	6.6	4.5	5.2
Mississippi Central	274	304	224	160	122	217	296	328	279	247	252	280	8.7	9.6	7.2	5.1	3.9	6.9
Nashville,Chattanooga & St.Louis	106	100	122	230	208	153	149	139	184	382	425	256	3.9	3.7	4.5	8.4	7.6	5.6
New Orleans & Northeastern	91	105	119	147	207	134	158	176	208	304	519	273	3.0	3.4	3.9	4.8	7.1	4.4
Norfolk Southern	340	322	355	320	272	322	212	213	330	387	439	316	12.3	11.7	11.5	10.6	9.3	11.1
Seaboard Air Line	185	183	186	191	207	190	206	217	264	336	430	291	6.1	6.0	6.1	6.3	6.9	6.3
Southern Ry.	186	184	176	158	154	172	279	286	310	304	350	306	6.0	5.9	5.7	5.1	5.0	5.5
Tennessee Central	250	291	329	213	151	247	204	301	451	344	287	317	8.3	9.6	10.9	7.0	5.0	8.2
Western Ry.of Alabama	153	328	232	242	250	241	193	413	334	403	480	365	5.0	10.8	7.6	7.9	8.2	7.9
Yazoo & Mississippi Valley	194	227	281	278	328	262	193	240	378	463	625	380	6.3	7.4	9.2	9.1	10.8	8.6
Total	169	174	186	186	187	180	196	211	269	318	372	273	5.6	5.8	6.2	6.2	6.3	6.0

Table B

Table B

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1940 to 1944, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wooden cross tie renewals per mile of maintained track						Aggregate cost of new wooden cross tie renewals per mile of maintained track						Per cent new wooden cross tie renewals to all ties in track					
	1940	1941	1942	1943	1944	5 year average	1940	1941	1942	1943	1944	5 year average	1940	1941	1942	1943	1944	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western	124	133	136	89	108	118	$131	$138	$152	$121	$192	$147	4.2	4.5	4.6	3.0	3.6	4.0
Chicago Great Western	163	163	136	120	180	152	202	205	194	188	341	226	5.5	5.5	4.6	4.0	6.1	5.1
Chicago,Milwaukee,St.Paul & Pac.	174	166	172	145	161	164	205	197	219	226	279	225	5.6	5.4	5.6	4.7	5.2	5.3
Chicago,St.Paul,Minpls.& Omaha	170	170	173	114	133	152	206	206	230	187	256	217	5.7	5.7	5.9	3.8	4.5	5.1
Duluth,Missabe & Iron Range	102	135	105	127	89	112	150	200	153	225	185	183	3.4	4.5	3.5	4.2	3.0	3.7
Duluth,South Shore & Atlantic	204	204	174	145	147	175	130	154	155	157	224	164	7.2	7.2	6.1	5.1	5.0	6.1
Duluth,Winnipeg & Pacific	318	326	330	356	342	334	230	294	356	520	682	416	10.9	11.1	11.3	12.1	11.6	11.4
Great Northern	143	152	150	156	338	188	185	196	212	279	330	240	4.6	4.9	4.8	5.1	5.5	5.0
Green Bay & Western	348	391	299	212	392	328	308	365	365	368	793	440	12.1	13.6	10.4	7.4	13.6	11.4
Lake Superior & Ishpeming	183	185	175	77	134	151	127	128	144	100	213	142	6.1	6.2	5.8	2.6	4.5	5.0
Minneapolis & St.Louis	225	221	216	117	135	183	204	189	217	152	221	197	7.4	7.3	7.2	3.9	4.5	6.1
Minneapolis,St.Paul & S.S.Marie	138	138	126	86	84	114	117	124	128	120	147	127	4.7	4.7	4.3	2.9	2.9	3.9
Northern Pacific	133	137	139	119	107	127	156	157	184	178	172	169	4.6	4.7	4.8	4.1	3.7	4.4
Spokane International	328	350	368	387	435	374	150	174	296	370	506	299	11.6	12.0	12.6	13.3	15.0	12.9
Spokane,Portland & Seattle	264	277	212	225	492	294	306	361	311	348	932	452	9.1	9.6	7.0	7.4	16.2	9.9
Total	153	156	153	127	144	147	172	177	192	197	258	199	5.1	5.2	5.1	4.2	4.8	4.9
CENTRAL WESTERN REGION:																		
Alton R.R.	244	234	194	177	181	206	323	307	288	281	363	312	8.1	7.8	6.4	5.9	6.0	6.8
Atchison,Topeka & Santa Fe	91	101	105	80	78	91	113	129	135	102	116	119	3.0	3.3	3.5	2.6	2.6	3.0
Chicago,Burlington & Quincy	136	186	193	185	182	176	175	227	267	278	336	257	4.4	6.0	6.2	6.0	5.9	5.7
Chicago,Rock Island & Pacific	109	103	110	117	165	121	104	107	119	140	331	160	3.6	3.5	3.7	3.9	5.5	4.0
Colorado & Southern	101	106	93	111	99	102	120	134	123	190	188	151	3.3	3.5	3.1	3.7	3.3	3.4
Colorado & Wyoming *	-	99	103	64	69	-	-	175	196	178	195	-	-	3.5	3.7	2.2	2.4	-
Denver & Rio Grande Western	55	42	33	29	40	40	58	48	45	49	74	55	1.8	1.3	1.1	0.9	1.3	1.3
Denver & Salt Lake	131	137	229	125	229	170	169	183	400	257	691	340	4.3	4.5	7.5	4.1	7.6	5.6
Fort Worth & Denver City	88	70	82	99	117	91	100	83	110	163	174	126	3.1	2.3	2.7	2.4	2.9	2.7
Northwestern Pacific	173	184	215	231	297	220	130	154	275	384	516	292	5.9	6.4	7.4	8.0	10.2	7.6
Southern Pacific Co.- Pac.Lines	102	102	106	115	150	115	115	121	145	175	256	162	3.3	3.4	3.5	3.7	4.8	3.7
Toledo,Peoria & Western	217	164	112	95	61	130	298	205	156	135	107	180	6.9	5.2	3.5	3.0	1.9	4.1
Union Pacific	160	187	196	164	160	173	178	208	237	223	246	218	5.7	6.6	6.9	5.8	5.7	6.1
Utah Ry.	75	127	87	69	52	82	159	267	212	168	122	186	2.6	4.5	3.1	2.4	1.8	2.9
Western Pacific	352	331	135	164	293	255	402	389	178	238	517	345	11.9	11.1	4.5	5.5	9.8	8.6
Total	122	135	136	125	139	131	142	160	176	177	242	179	4.1	4.5	4.5	4.1	4.6	4.4
SOUTHWESTERN REGION:																		
Beaumont,Sour Lake & Western	114	96	152	192	255	162	130	110	199	317	484	248	3.8	3.2	5.1	6.4	8.6	5.4
Burlington-Rock Island	92	69	62	73	95	78	91	67	67	65	117	81	2.9	2.2	1.9	2.3	3.0	2.5
International-Great Northern	121	111	131	112	102	115	123	123	166	169	190	154	4.0	3.7	4.4	3.7	3.4	3.8
Kansas City Southern	133	245	476	409	251	303	140	258	626	650	439	423	4.2	7.7	15.0	12.9	7.9	9.5
Kansas,Oklahoma & Gulf	53	42	37	48	60	48	52	44	43	72	104	63	1.8	1.4	1.2	1.6	2.0	1.6
Louisiana & Arkansas	198	246	528	718	448	428	173	247	676	1180	832	622	6.1	7.6	16.3	22.1	13.7	13.2
Midland Valley	70	63	56	61	68	64	72	67	65	88	99	78	2.4	2.1	1.9	2.1	2.3	2.2
Missouri & Arkansas	308	344	332	355	384	345	147	180	227	353	573	296	9.9	11.0	10.7	11.4	12.3	11.1
Missouri-Kansas-Texas Lines	76	131	322	324	325	236	73	139	471	549	630	372	2.4	4.2	10.2	10.3	10.3	7.5
Missouri Pacific	167	169	146	105	95	136	173	184	181	147	160	169	5.4	5.5	4.7	3.4	3.1	4.4
New Orleans,Texas & Mexico	130	118	166	301	168	177	148	135	213	242	338	215	4.2	3.9	5.4	9.8	5.5	5.8
Oklahoma City-Ada-Atoka	122	198	111	158	287	215	45	115	286	259	248	190	4.2	6.9	10.8	5.5	10.0	7.5
St.Louis,Brownsville & Mexico	131	134	154	153	186	152	142	147	200	249	354	218	4.3	4.4	5.1	5.1	6.2	5.0
St.Louis-San Francisco	120	112	122	132	132	124	123	116	148	186	208	156	3.8	3.6	3.9	4.2	4.2	3.9
St.Louis,San Fran.& Texas	182	153	116	104	91	129	185	153	132	135	139	149	5.8	5.0	3.7	3.3	2.9	4.1
St.Louis Southwestern Lines	166	182	159	168	206	176	193	215	225	274	380	255	5.2	5.8	4.9	5.3	6.5	5.5
San Antonio,Uvalde & Gulf	116	92	101	113	172	119	125	96	128	159	194	140	4.0	3.2	3.5	3.9	6.0	4.1
Texas & New Orleans	143	139	149	110	128	134	125	124	156	130	201	147	5.2	5.1	5.5	4.0	4.7	4.9
Texas & Pacific	112	171	211	262	232	198	114	177	266	365	411	267	3.8	5.8	7.2	9.0	7.9	6.7
Texas Mexican	193	155	174	104	104	146	203	193	272	178	187	207	6.1	4.9	5.5	3.3	3.3	4.6
Total	136	150	187	179	169	164	135	155	236	265	293	217	4.5	4.9	6.2	5.9	5.5	5.4
Grand total, United States	128	140	145	136	144	139	156	176	206	226	280	209	4.3	4.7	4.8	4.5	4.8	4.6
CANADIAN ROADS:																		
Canadian National	214	208	192	170	165	190	173	182	186	187	217	189	7.6	7.1	6.6	5.8	5.6	6.5
Canadian Pacific	144	139	139	141	145	142	122	131	146	168	207	155	5.1	4.9	4.9	4.9	5.1	5.0
Temiskaming & Northern Ontario	267	309	228	176	191	234	174	205	171	144	172	173	8.8	10.6	7.9	6.0	6.6	8.0

* Not Class I until January 1, 1941.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.
from Annual Reports of Class I railways to the Interstate Commerce Commission.
June 30, 1945

Switch.—The transverse member of the track structure which is longer than but functions as does the cross tie and in addition supports a crossover or turnout. *3*

Page 3–20. Delete the heading, "Proper Size of Hole for Preboring" and substitute: Size of Holes Bored for Spikes. This change provides for holes of the sizes which are stipulated as proper, whether bored prior to preservative treatment or later.

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

John Foley (chairman, subcommittee), S. B. Clement, J. G. Sutherland.

The statistics compiled annually to provide information regarding the number and the cost of the cross ties laid in replacement are supplied for 1944 in Tables A and B.

An increase over 1943 in the number of ties applied probably reflects improvement in the manpower situation resulting from the utilization of imported track labor.

The reapplied second-hand ties again declined, to fewer than the number used in any of the past several years, showing that ties are being displaced only when the maximum service they can render has been obtained where they were first installed.

The usefulness of these renewal statistics depends on the reliability of the data submitted by the railroads and the care exercised in computing the averages, percentages, and units derived from them. Errors in the reports of tie renewals for 1943 and 1944 make necessary the following corrections:

1943. Percent renewal to all ties in track (Column 15); Fort Worth & Denver City should be 3.3 instead of 2.4.

1944. Estimated total cross ties in all maintained tracks (Column 11); Fort Worth & Denver City should be 2,846,230 instead of 3,846,230.
Total for Central Western Region should be 224,991,508 instead of 225,991,508.
Grand total for United States should be 994,624,198 instead of 995,624,198.
Average number of ties per mile of maintained track (Column 12); Fort Worth & Denver City should be 3,007 instead of 4,064.
Total for Central Western Region should be 3,012 instead of 3,026.
Grand total for United States should be 3,003 instead of 3,006.
Percent renewal to all ties in track (column 15); Fort Worth & Denver City should be 3.9 instead of 2.9.
Number of new wood cross tie renewals per mile of maintained track; Great Northern should be 169 instead of 338 for 1944 and 154 instead of 188 for the 5-year average.
Percent new wood cross tie renewals to all ties in tracks; Fort Worth & Denver City should be 3.3, 3.9, and 3.1 instead of 2.4, 2.9 and 2.7 (1943, 1944 and 5-year average).

It is hoped that when members correct their copies of the reports involved, they will scrutinize the figures for their own railroads, and call attention to any errors which exist.

Report on Assignment 5

Cause and Control of Splitting in Railroad Ties

R. E. Butler (chairman, subcommittee), M. L. Bardill, R. S. Belcher, W. C. Bolin, W. H. Brameld, H. F. Brown, W. J. Burton, S. B. Clement, H. R. Duncan, B. D. Howe, R. B. Midkiff, J. G. Sutherland, A. W. White.

This is a progress report submitted as information.

The conditioning of ties by subjecting them to condensing vapors which accelerate their drying as a procedure in substitution for air seasoning was referred to in the 1944 report of the committee. The results of the experimental vapor processing of ties to remove their moisture without lengthy air exposure led the Southern Railway to authorize the Taylor–Colquitt Company to dry the ties for the former by the procedure described below.

The effectiveness of vapor drying in controlling the splitting of ties depends on how green they are. Ties which are partly seasoned do not lend themselves to effective vapor drying, which is another reason why ties should be moved from the woods without delay.

If vapor-dried ties check and split less than air-seasoned ties before and after they are installed in track, the procedure will constitute a real contribution to a reduction in renewals. If oak ties can be satisfactorily dried by this procedure in 15 hours instead of 15 months, many acres of seasoning yard space can be saved.

The Vapor Drying Process For Conditioning of Wood

The initial development work on this process was begun with laboratory equipment at the wood preserving plant of the Taylor–Colquitt Company, Spartanburg, S. C., in 1939. In 1940 a small experimental unit was constructed with a 16-in. by 72-in. cylinder as the drying chamber. After thorough tests in this unit were completed, a pilot plant was erected in 1942. The drying chamber in this unit is a cylinder 26 ft. long and 3 ft. in diameter. In June 1945 operation of the process on a commercial scale began with a regulation creosoting cylinder, 8 ft. by 115 ft., being utilized as the drying chamber. The necessary equipment for operating the vapor drying process was added to an existing creosoting unit which is so arranged that the vapor drying operation can be followed by any pressure process for preservative treatment. The only additional pieces of equipment required for this conversion are a condenser, separatory tank, condensate return tank, condensate return pump, and an evaporator.

The vapor drying process utilizes two principles of heat transfer that result in greatly accelerated rates of drying: (1) A relatively high temperature range which heretofore has been limited to the drying of thin veneer, for which the time of exposure to the temperature required is so short that deterioration of the wood does not take place under the conditions employed; (2) exposure of the material to condensing vapors which accelerate the drying through the large amount of latent heat liberated during the condensation of the vapor. The chief causes of deterioration of wood when it is subjected to heating in steam or air, or in a mixture of them in the temperature range above the boiling point of water and below the temperature of thermal decomposition (212 deg. F. to about 400 deg. F.) are hydrolysis from the action of steam and oxidation in the presence of air. These factors are eliminated in the operation of the vapor drying process by conducting the drying in an inert atmosphere of organic compounds that serves as the means of conveying the heat to the material being dried.

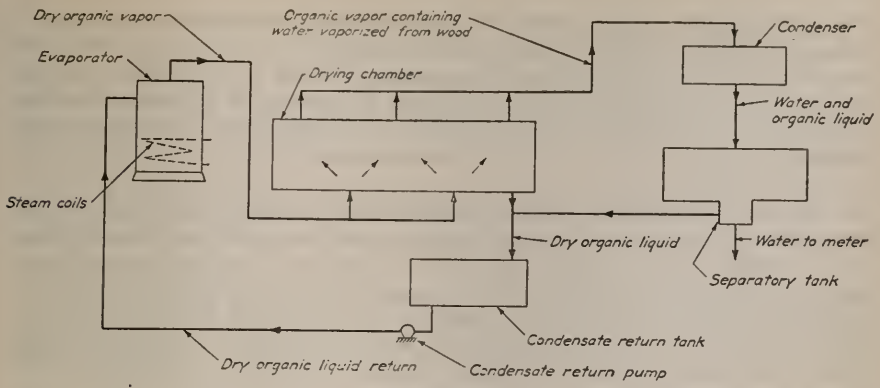

Fig. 1.

Fig. 1 illustrates diagrammatically the apparatus involved and the progress of the drying agent in the operation of the vapor drying process as described below:

The organic drying agent in the evaporator or boiler is heated to its boiling point by any suitable means, such as a steam coil. The vapor from the boiling liquid is then introduced into the drying chamber containing the material to be dried, at several points for proper distribution. On contacting the cold wood this hot vapor condenses on the surface of the wood at the start of the operation, giving up its latent heat of vaporization, which supplies heat to vaporize the water from the wood. The excess organic liquid produced by condensation that is not absorbed by the wood flows from the drying chamber to the condensate return tank, whence it is returned by means of the pump to the evaporator, where it is revaporized. As heating is continued by maintaining the flow of organic vapor to the drying chamber, the temperature in that vessel rapidly rises until it is approximately the same as that of the vapor in the evaporator. By this time the temperature of the surface of the wood has risen so high that the line of organic vapor condensation has moved beneath the surface of the wood, and the flow of organic condensate from the drying chamber to the condensate return tank is materially lessened in volume. Since the drying chamber and its contents have then reached a temperature near the boiling point of the organic liquid, an excess of organic vapor is present and this vapor, containing water vaporized from the wood, is forced by incoming vapor from the evaporator into the drying chamber discharge manifold and thence into the condenser. The mixed condensate of drying agent and water is directed into the separatory tank, where a simple gravity separation takes place. The separated organic liquid is then conducted to the condensate return tank, where it joins the condensate from the cylinder to be pumped back to the evaporator to be revaporized. The separated water is then passed through a water motor which can be read from time to time to determine the progress of drying of the wood.

The circulation of the organic vapor through the system is continued until the water-meter readings show that the amount of water removed is sufficient to bring the wood to the required state of dryness. This vapor distills water from the wood and transports it to the condenser and thence into the separator where the organic liquid is separated from the water and returned to the evaporator to begin a new circuit. At the end of the drying operation the dried wood contains a large amount of organic liquid condensed in it during drying. Both the wood and the drying agent it contains are at a temperature high enough to permit vaporizing the latter from the wood by

the application of a vacuum. At this stage the inflow of vapor from the evaporator is stopped by closing a valve on the vapor line between the evaporator and the drying chamber. A vacuum is then drawn on the drying chamber and its contents, and the organic liquid vaporized from the wood thereby is recovered at the condenser. At the end of the vacuum cycle the dry wood, which is now virtually free of the organic drying medium, is ready to be removed from the drying chamber if it is not to be given further treatment therein.

The part of the process involving circulation of the organic vapor through the drying chamber to remove water from the wood is usually conducted at atmospheric pressure, in which case the desired temperature of operation is obtained by selecting an organic compound whose boiling point at atmospheric pressure gives the temperature desired. For example, if it is desired to maintain a temperature of 280 deg. F. at atmospheric pressure in the drying chamber, the chemical compound xylene, whose boiling point at atmospheric pressure is 280 deg. F., might be used. If a temperature of 350 deg. F. were required the coal-tar distillate known as high flash naphtha would be satisfactory. If a temperature of 240 deg. F. is required and the only available drying agent at hand were xylene, the conditioning could be accomplished by conducting the vaporization and circulation of xylene through the system under a vacuum of about 14 in. of mercury, which is the pressure at which xylene boils at 240 deg. F. Thus a single organic compound permits a wide range of temperatures through the adjustment of the pressure conditions in the vapor drying chamber. This flexibility, coupled with the fact that a very large number of commercially available organic liquids with widely varying boiling points are satisfactory for use in the vapor drying process, extends the available temperature range much farther. Choice of the temperature to be used is governed by such considerations as the operating temperature of the processed steam available at a given plant and the availability of the drying material in the locality of the plant.

Since the material being dried by the vapor process is in an atmosphere of organic vapor that does not attack the wood, and this atmosphere is free of oxygen which would cause deterioration of the wood by oxidation and is also virtually free of steam, which would cause deterioration by hydrolysis, it is possible to operate the drying in the relatively high temperature range of 212 to 400 deg. F. without injury to the wood. It should be noted that the only steam present in the drying atmosphere is that produced by vaporization of water from the wood, and since this is kept at a very low concentration by the large volume of incoming dry organic vapor the usual hydrolysis action from the presence of steam is prevented.

Practice at Spartanburg

At Spartanburg the practice has been to air season red oak cross ties in 1 by 8 stacks for at least 15 months, during which period their moisture content is reduced from about 70 percent to about 40 percent. The ties so seasoned show the splits in their ends and the checks on their faces which are characteristic of air-dried red oak.

The conditioning of unseasoned oak by the vapor drying process is briefed in the following figures from a charge of 800 ties conditioned commercially and subsequently treated with 60—40 creosote-coal tar solution:

Heating in vapor at 270 deg. F.	12	hours
Vacuum after vapor (24 in. of mercury)	2	hours
Water removed	3,980	gal.
	32,705	lb.
	11.5	lb. per cu ft.
Average initial moisture content	72.6	percent
Average final moisture content	41.0	percent

All the ties subjected to vapor drying as outlined above in experimental or commercial charges came from the treating cylinder far less checked than if they had been air seasoned. Such ties as were sectioned showed slits along most of the medullary rays which began ¼ in. to ½ in. below the surface and extended inward ¾ to 1½ in., depending on the drying period. These slits seldom exceeded $\frac{1}{16}$ in. wide, and were not present within 2 in. of the ends of the ties.

A test track containing red oak ties conditioned by the vapor process as described above is being maintained by the Southern Railway near Spartanburg on the Asheville division, and after two years of service the ties continue less checked and split than the air-seasoned ties installed at the same time.

Tests of the strength of ties conditioned by the vapor process were made at the laboratory of the engineer of tests, Southern Railway, Alexandria, Va., and at Clemson College, Clemson, S. C., and the results are shown in Table 1.

TABLE 1

Kind of Wood	*Condition of Ties*	*Modulus of Rupture in Static Bending lb. per sq. in.*	*Fiber Stress at Proportional Limit in Compression Perpendicular to Grain lb. per sq. in.*
Oak	Green	9560	804
	Air seasoned	8754	687
	Vapor dried	8025	605
Black and red gums	Green	Not determined	712
	Air seasoned	Not determined	*552
	Vapor dried	Not determined	663
Beech	Green	Not determined	911
	Vapor dried	Not determined	825

* Strength reduction in air seasoning resulted from fungus infection.

In view of the reduced strength from vapor drying shown above and because the loss in strength was evidently due to the ray slits heretofore described, a modification of the drying procedure outlined above was evolved. This consisted of alternating periods of exposure to heating in vapor and of vacuum instead of the continuous heating ended by a single vacuum. The effect of the alternating procedure is to maintain a more uniform moisture gradient and so eliminate the formation of slits along the medullary rays. Ties subjected to the alternating procedure proved as strong as their green controls when tested for the physical properties named above.

However, ties vapor dried by the alternating procedure, although free of external or internal checks or splits when installed in track, develop in service more checks and splits than ties vapor dried by the continuous heating procedure; but do not split as extensively as do air seasoned ties.

The explanation is made by the proponents of the vapor drying process that ties conditioned by the continuous heating procedure show virtually no external checking, even after two years of service in track, because the internal slits produced by that procedure equalize the stresses that develop from the shrinking and swelling of wood exposed to moisture variations, and thus prevents the formation of checks and splits sufficient in size to impair the serviceability of a tie.

Those interested in vapor drying procedures are satisfied from observations of the ties in track that, despite the loss in their initial strength, the ties with ray slits will give longer service than ties which have undergone no reduction in strength because they were vapor dried by the alternating heating procedure.

West coast woods also have been conditioned by the vapor process (and subsequently treated with creosote) as follows:

Douglas Fir

Heating in vapor at 330 deg. F.	5.5 hours
Vacuum after vapor (23 in. of mercury)	2 hours
Water removed	6.6 lb. per cu. ft.
Average initial moisture content	42.4 percent
Average final moisture content	19.3 percent

Western Hemlock

Heating in vapor at 290 deg. F.	5.5 hours
Vacuum after vapor (23 in. of mercury)	1 hour
Water removed	4.6 lb. per cu. ft.
Average initial moisture content	55.3 percent
Average final moisture content	37.4 percent

The west coast woods were tested for strength at the Forest Products Laboratory, University of British Columbia, with the following results.

Kind of wood	*Condition of ties*	*Fiber stress at proportional Limit in compression perpendicular to grain lb. per sq. in.*	
		Incised	*Unincised*
Douglas fir	Green	396	496
Douglas fir	Vapor dried	355	433
Western hemlock	Green	379	337
Western hemlock	Vapor dried	386	312

Report on Assignment 6

Ways and Means for Retarding the Destruction of Ties by Mechanical Wear

F. G. Campbell (chairman, subcommittee), M. L. Bardill, R. S. Belcher, T. E. Bliss, H. J. Bogardus, W. C. Bolin, W. H. Brameld, H. F. Brown, W. J. Burton, R. E. Butler, S. B. Clement, R. L. Cook, H. R. Duncan, T. H. Friedlin, W. E. Gardner, L. E. Gingerich, B. D. Howe, C. T. Jackson, R. H. Jordan, Roy Lumpkin, L. E. Peterson, Arthur Price, E. F. Salisbury, W. D. Simpson, J. G. Sutherland, C. D. Turley, A. W. White.

This report is presented as information.

Not being able to do the traveling necessary for first-hand inspections, the subcommittee endeavored to ascertain by correspondence with its members and others, the methods and devices used, or suitable for use, in retarding the mechanical destruction of ties. The committee is appreciative of the assistance rendered by those who are not members of the subcommittee.

Mechanical wear leading to the destruction of ties may be described briefly as the deterioration of the tie resulting from the passage of traffic and which can be more specifically described as rail cutting, plate cutting, breaking, shattering, crushing, abrasion by ballast, and spike killing. The items affecting tie destruction by mechanical wear, but not necessarily in order of importance, are:

Size of rail
Tie plate
  (a) Size
  (b) Type
  (c) Application
Track maintenance
Adzing and boring of ties
Type of rail joint
Continuous welded rail
Rail anchors

Size of Rail

Under like conditions of traffic, maintenance and track structure, damage to ties by rail cutting decreases as the weight of rail increases, although not necessarily in direct proportion to such increase.

Tie Plates

(a) *Size.*—There are many types and sizes of tie plates in use, most of which prevent rail cutting of ties. Tie plates also retard the destruction of ties from other types of mechanical wear, with the possible exception of breakage and ballast abrasion. The proper size and type of tie plate to be used with various weights of rail is a subject which is being studied by another committee. It may be said, however, that if volume of traffic, weight of rail, and standard of maintenance are equal, the damage to the tie through plate cutting, crushing and shattering will decrease as the size of the tie plate increases.

(b) *Type.*—Some tie plates have from two to four ribs on the bottom of the plate perpendicular to the tie, others have very low ridges in the form of grids on the bottom of the plate, and others have smooth bottoms. Ribs or corrugations on the bottom of tie plates reduce the amount of regaging which must be done, with a consequent reduction in spike killing; however, in some earlier types of tie plates, the ribs were so high that they damaged the tie by cutting into the wood fiber. It is not generally contended that the ribs on the newer type of tie plates damage ties, but the general tendency at the present time is toward the greater use of the smooth-bottom tie plate.

(c) *Application.*—Tie plates are held in place by the weight of the rail and by gage spikes, which are those spikes driven in contact with the base of the rail, and by anchor spikes, which are those spikes driven through the tie plate but not immediately adjacent to the rail. Methods of application vary from the use of gage spikes only (where ribbed tie plates are used), to the use of gage spikes plus two or four anchor spikes (where smooth-bottom tie plates are used). Anchor spikes may be cut spikes, screw spikes without spring washers, or screw spikes with double spring washers. Anchor spikes are intended to serve two purposes: (1) To aid in holding the rail to proper gage, especially on curves, and (2) to prevent movement of the tie plate independently of the tie. Where gage is held more nearly constant, spike killing is reduced. If movement of the plate on the tie is prevented, plate cutting is reduced. It is generally con-

ceded that the use of cut spikes as anchor spikes aids in maintaining gage but does not prevent movement of the plate on the tie. If the latter is accomplished, more elaborate anchorage, such as screw spikes with spring washers, must be used.

Track Maintenance

Track maintenance, which includes the type and condition of the ballast and drainage, affects the mechanical wear on ties. Where track is so maintained as to require a minimum of spot surfacing and lining, destruction of ties through ballast abrasion is reduced to a minimum. Center-bound track, a condition resulting from poor ballast maintenance, will cause ties to break and, conversely, this type of tie destruction is practically nil in well-maintained track.

Poor track drainage often causes the ties to be in contact with water a sufficient length of time to become softened. A tie in this condition is much more susceptible to any type of mechanical wear than is a dry tie.

Adzing and Boring of Ties

Adzing provides a uniform seat for the tie plate, thus reducing the mechanical wear which results from seating the plate on an uneven surface. This is especially true of hewed ties.

Spikes driven into bored holes have better holding power and cause less damage to the wood fiber. This should reduce spike killing. Boring of holes completely through the tie provides a drain and thus reduces the probability of the tie softening through the retention of water.

Type of Rail Joint

Ties at rail joints suffer more mechanical wear than do intermediate ties. Where the slotted angle-bar type of rail joint is used, spike killing in joint ties is especially prevalent. Impact of wheel loads at the joint is especially conducive to plate cutting crushing, and shattering. The added amount of tamping and raising required at joint ties over that required at intermediate ties increases ballast abrasion. All of these conditions, except spike killing, are brought about by vertical movement of the rail ends at the joint. This vertical movement, under heavy traffic, is less with a long joint bar than a short joint bar, assuming that each is properly applied or, in other words, if other conditions are equal, the use of a six-hole 36-in. joint bar rather than a four-hole 24-in. joint bar will, under heavy traffic, reduce mechanical destruction of ties at the joint.

Continuous Welded Rail and Rail Anchors

Continuous welded rail eliminates the excessive mechanical wear of ties at rail joints.

Rail anchors properly applied will retard rail running, which causes mechanical wear of ties by forcing added movement of the tie plate on the tie, and results in a greater tendency to both plate cutting and spike killing.

Conclusion

The tie plate and the method of its application are undoubtedly the most important items of track design affecting the destruction of ties by mechanical wear. The committee considers the average tie plate now in use, especially on heavy-traffic lines, too small to adequately protect the tie.

Fastening the tie plate to the tie with screw spikes and spring washers is required practice on a few railroads. The sizes of the tie plates used in these cases are generally

somewhat in line with the more recent AREA specifications for tie plates. There seems to be no question that the large tie plates so applied, with either 36-in. rail joints or continuous welded rail in combination with a high standard of maintenance, furnish the highest type of protection against mechanical wear of ties. Apparently the only reason that this method of fastening plates to ties is not in wider use is possible doubt as to whether the greater cost thereof is offset in all cases by the extended service life of the tie.

Report on Assignment 7

Reasons For the Removal of Treated Ties

C. D. Turley (chairman, subcommittee), M. L. Bardill, R. S. Belcher, T. E. Bliss, H. J. Bogardus, W. C. Bolin, W. H. Brameld, H. F. Brown, W. J. Burton, R. E. Butler, F. G. Campbell, S. B. Clement, R. L. Cook, H. R. Duncan, T. H. Friedlin, W. E. Gardner, L. E. Gingerich, B. D. Howe, C T. Jackson, R. H. Jordan, Roy Lumpkin, R. B. Midkiff, L. E. Peterson, Arthur Price, W. W. Rohrbaugh, E. F. Salisbury, W. D. Simpson, J. G. Sutherland, A. W. White.

This is a progress report, submitted as information.

The subject was assigned in 1944, and the plan of study decided upon was to make field inspections each year on a number of railroads to observe first hand, ties which had been removed from track, and to determine as far as possible the various causes of their removal. No inspections have been made to date, due to the restrictions placed on travel, but it is hoped that conditions will improve sufficiently to permit inspections in 1946.

In order that uniform and comparable data can be recorded on such inspections, and to provide a guide to railroads in compiling data on the performance of cross ties, it is desirable to establish a list of reasons why ties are removed from track. Such a list has been prepared in statement form, so that records can be compared with similar records of other railroads.

Reasons for Removal of Treated Ties

Railroad _____
Location _____
Date of Inspection _____

Kind of wood	Size of tie	Kind of treatment	Decay		Mechanical Wear						Defects Exceeding AREA Specifications						Other Causes				Total number of ties removed	Remarks
			Throughout the tie	Within plate bearing area	Crushed	Shattered	Spike killed	Plate cut	Broken	Tamp killed	Split	Knots	Holes	Shakes	Cross grain	Derailments	Dragging equipment	Burned	Removed account track changes		

Form of Statement for Recording Reasons for Removing Treated Ties.

The primary purpose of this assignment is to determine the causes which make necessary the removal of ties from track so that corrective action can be taken. For that reason, the initial cause of the trouble, rather than the physical condition of the tie when it is removed from track, should be recorded as the cause. As an example, splits that enter the heartwood of a tie expose untreated and unprotected wood and thus cause

decay. To reduce the number of such failures, it is necessary to obtain ties with less tendency to split, and the reason for removal should be listed as split, not decay.

If failures from decay on a given railroad compare unfavorably with those on other railroads, the production, seasoning and treatment methods and practices should be checked. If failures from mechanical wear compare unfavorably, the track structure should be carefully analyzed; and if removals due to natural defects in the wood seem excessive, cross tie specifications and inspection should be given special attention. Listed under other causes are items largely controlled by the operating department and not directly affected by the quality of ties. The peculiarities of the various woods and the effects of wide variations in climatic conditions also require special study and consideration.

In the form submitted, the term, spike killed, refers to the condition presented by a tie in which the spike holes have become enlarged to such an extent that they will no longer hold the spikes. Tamp killed refers to the rounding off of the lower edges of a tie by tamping picks or power tamping tools and a consequent loss of effective support for the track.

Report of Committee 17—Wood Preservation

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions..... page 136

2. Service test records of treated wood.

   Progress report, presented as information..... page 141

3. Destruction by marine organisms and possible ways of prevention.

   No report.

4. Specifications for creosote-petroleum mixtures.

   No report.

5. Destruction by termites and possible ways of prevention.

   Progress report, presented as information..... page 142

6. New impregnants and procedures proposed for increasing the life and serviceability of forest products.

   No report.

7. Incising forest products.

   No report.

8. Use of straight coal tar for tie treatment and results obtained.

   No report.

9. Critically review the specifications for creosote with attention to changes in the process of manufacture and with regard to limiting the residue above 355 deg. C.

   No report.

Bulletin 456, December 1945.

10. Development of specifications for the treatment of wood to make it fire resistant, including: (a) methods of treatment; (b) chemicals; (c) wood preservatives and amount thereof to be added to fire-resistive salts; (d) performance test methods; and (e) interpretation of test results.

No report.

11. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

No report.

The Committee on Wood Preservation,
H. R. Duncan, *Chairman.*

Report on Assignment 1

Revision of Manual

John Foley (chairman, subcommittee), W. P. Arnold, R. S. Belcher, S. J. Buckman, C. S. Burt, W. F. Clapp, A. J. Loom, L. B. Shipley, Hermann von Schrenk.

The following corrections of the Glossary are recommended for the reasons given below:

Delete terms not in Chapter 17, as required by Board Committee on Manual policy:

Air (preliminary), air dried, Allardyce process, annual ring, anti-checking iron, bacteria, bleeding, Boulton process, Card process, charge (verb), decay (incipient), density, durability, expansion factor, fiber saturation point, free carbon fungus, impervious, impregnation, kick-back, kyanize, leach, moisture (hygroscopic), mold, oil (wet), permeability, refractory timber, refusal point retort, sap drum, sap stain, seasoning (artificial), ship worm, spores, springwood, summerwood, tank (all 6), tar acids, test (all 3), tie (adzed, bored), toxic, treatment (brush, butt, non-pressure, open-tank, spray, surface), ullage, vacuum (initial), Wellhouse process, zinc-tannin process.

Delete 17 because it is not the only chapter involved, and substitute the number or numbers of the committee or committees originating the term defined, as shown below:

Dating nail *3,* decay *3, 7, 17,* heartwood, *3, 7, 17,* incising *3, 17,* sapwood *3, 7, 17.*

Revise the definitions of the following terms in accordance with current conceptions of the terms:

Air, Initial.—Compressed air forced into the wood in a treating cylinder just prior to the introduction of the preservative and maintained at the desired pressure during the filling of the cylinder. *17*

Borer, Increment.—Delete and substitute:

Borer, Penetrance.—An auger with a hollow shaft which as turned fills with a core of wood, which is extracted for determining the depth of penetration by a preservative or the width of the sapwood. *17*

Borers, marine.—Delete "ship worms".

Bethell Process.—Full-cell pressure treatment of wood with an oil preservative. *17*

Burnett Process.—Full-cell pressure treatment of wood with a salt preservative. *17*

Creosote-Coal Tar Solution.—Creosote with coal tar added in prescribed proportions. *17*

Decay.—Delete "Dote; rot". Credit to *3, 7, 17*

Fungus.—Delete and substitute:

Fungi.—Low forms of plant life without roots, stems, or leaves, which contain no chlorophyl and derive nourishment from organic matter. *17*

Grouping.—Sorting forest products into groups according to their sapwood content, size, strength, and treatability. *3, 17*

Heartwood.—Inner core of the tree trunk comprising the annual rings containing nonliving elements; usually darker in color than sapwood. *3, 7, 17*

Sapwood.—Outer layers of growth in a tree, exclusive of bark, which contain living elements; usually lighter in color than heartwood. *3, 7, 17*

Solution.—Delete and substitute: solutions, wood-preserving. Liquid combinations of toxic salts and water, creosote and coal tar, or creosote and petroleum. *17*

Wood preservation.—Delete "preservation" and substitute "preserving".

Add the following definitions to cover terms adopted in 1945.

Creosote-Petroleum solution.—Creosote with petroleum added in prescribed proportions. *17*

Seasoning, Air.—Evaporation of moisture from wood by exposure to the atmosphere, in the open or under cover without artificial heat. *17*

Pages 17–3 and 4. Delete the matter on both pages and substitute the following in order to bring the recommendation up to date and in harmony with other parts of Chapter 17.

REQUISITIONING PRESERVATIVELY-TREATED WOOD

1946

1. Requisition for wood treated with a preservative oil or salt should stipulate the following:

(a) *Item.*—The item or items which are to be supplied and the dimensions required.

(b) *Wood.*—The kind or kinds of wood which will be accepted.

(c) *Quality.*—An AREA or other specification or grading rule for the item ordered which assures the fitness of each piece for its intended use.

(d) *Machining.*—The adzing, boring, chamfering, framing, gaining, surfacing, trimming, or other fabrication which may be required.

(e) *Preservative.*—An impregnant which meets the requirements of one of the AREA specifications for preservatives: i.e., creosote, grade one; creosote-coal tar solutions; creosote-petroleum solution; zinc chloride.

(f) *Treatment.*—A treating procedure which conforms to the AREA specifications for treating processes.

(g) *Retention of preservative.*—When an AREA specification for preservative treatment is not available to provide the least amount of preservative to be retained, the quantities in Table 1701 may be considered safe minimum net retentions, for the items listed when to be used under ordinary conditions. The full-

TABLE 1701.—MINIMUM NET RETENTION OF PRESERVATIVE[1]

A = Creosote. B = Creosote-coal tar solution. C = Creosote-petroleum solution. D = Zinc chloride.

Construction and maintenance of way item	Minimum net retentions Empty-cell process				Pounds per cubic foot Full-cell process[2]			
	A	B	C	D	A	B	C	D
Bridges and Trestles								
Sills	12	12	14	--	16	16	18	--
Posts	10	10	12	--	14	14	16	--
Caps	8	8	10	--	12	12	14	--
Bracing	8	8	10	--	12	12	14	--
Girts	8	8	10	--	12	12	14	--
Floor beams	8	8	10	--	12	12	14	--
Stringers	8	8	10	--	12	12	14	--
Ties	8	8	10	--	12	12	14	--
Guard timbers	10	10	12	--	14	14	16	--
Railing	6	6	--	1	10	10	--	1
Deck plank	8	8	10	--	12	12	14	--
Ballast plank	12	12	14	--	16	16	18	--
Tanks and Supports								
Sills	12	12	14	--	16	16	18	--
Posts	10	10	12	--	14	14	16	--
Caps	8	8	10	--	12	12	14	--
Bracing	8	8	10	--	12	12	14	--
Joists	8	8	10	--	12	12	14	--
Flooring	12	12	12	--	16	16	18	--
Staves	10	10	10	--	14	14	16	--
Rafters	8	8	10	--	12	12	14	--
Roofing	8	8	10	--	12	12	14	--
Frost boxing	10	10	12	--	14	14	16	--
Piers and Wharves								
Piles Inland	10	10	--	--	14	14	--	--
Marine	20	20	--	--	24	24	--	--
Sheet piling—Inland	10	10	--	--	14	14	--	--
Marine	20	20	--	--	24	24	--	--
Cribbing—Inland	10	10	--	--	14	14	--	--
Marine	20	20	--	--	24	24	--	--
Caps	10	10	12	--	14	14	16	--
Stringers	10	10	12	--	14	14	16	--
Bracing	10	10	12	--	14	14	16	--
Guard timbers	10	10	12	--	14	14	16	--
Ties	8	8	10	--	12	12	14	--
Decking	8	8	10	--	12	12	14	--
Posts	10	10	12	--	14	14	16	--
Fenders	10	10	12	--	14	14	16	--
Wales	10	10	12	--	14	14	16	--
Coaling and Ore Stations								
Sills	12	12	14	--	16	16	18	--
Posts	10	10	12	--	14	14	16	--
Caps	10	10	12	--	14	14	16	--
Bracing	8	8	10	--	12	12	14	--
Stringers	10	10	12	--	14	14	16	--
Joists	10	10	12	--	14	14	16	--
Bin lining	8	8	10	--	12	12	14	--
Rafters	10	10	12	--	14	14	16	--
Flooring	8	8	10	--	12	12	14	--
Chutes	8	8	10	--	12	12	14	--
Decking	8	8	10	--	12	12	14	--
Pockets and bins	8	8	10	--	12	12	14	--
Roofing	8	8	10	--	12	12	14	--
Truss Members								
5 in. and thinner	10	10	12	--	14	14	16	--
Over 5 in. thick	8	8	10	--	12	12	14	--
Tunnels								
Sills	12	12	14	--	--	--	--	--
Posts	10	10	12	--	--	--	--	--
Caps	10	10	12	--	--	--	--	--
Segments	--	--	--	1	--	--	--	--
Lagging	--	--	--	1	--	--	--	--
Struts	--	--	--	1	--	--	--	--
Buildings								
Foundation timbers	12	12	14	--	16	16	18	--
Posts and columns	10	10	12	--	14	14	16	--
Sills	12	12	14	--	16	16	18	--
Members above ground	8	8	8	1	12	12	14	1

Construction and maintenance of way item	Minimum net retentions Empty-cell process A	B	C	D	Pounds per cubic foot Full-cell process[2] A	B	C	D
Platforms								
Sills	12	12	14	--	16	16	18	--
Posts	10	10	12	--	14	14	16	--
Caps	10	10	12	--	14	14	16	--
Stringers	10	10	12	--	14	14	16	--
Bridging	8	8	10	--	12	12	14	--
Steps	8	8	10	--	12	12	14	--
Flooring	8	8	10	--	12	12	14	--
Stock Guards and Pens								
Sills	12	12	14	--	16	16	18	--
Posts	10	10	12	--	14	14	16	--
Fencing	10	10	12	--	14	14	16	--
Aprons	10	12	12	--	14	14	16	--
Studding	10	10	12	--	14	14	16	--
Sheathing	8	8	10	--	12	12	14	--
Rafters	8	8	10	--	12	12	14	--
Roofing	8	8	10	--	12	12	14	--
Fences								
Posts	6	6	8	--	10	10	12	--
Bracing	6	6	8	--	10	10	12	--
Stringers	6	6	8	--	10	10	12	--
Fencing	6	6	8	--	10	10	12	--
Gates	6	6	8	--	10	10	12	--
Stakes	6	6	8	--	10	10	12	--
Culverts and Drains								
Sills	12	12	14	--	16	16	18	--
Framing	10	10	12	--	14	14	16	--
Planking	10	10	12	--	14	14	16	--
Grillage	10	10	12	--	14	14	16	--
Bumping blocks	10	10	12	--	14	14	16	--
Conduit	8	8	10	--	--	--	--	--
Cross arms	6	--	--	--	--	--	--	--
Crossing plank	8	8	10	--	12	12	14	--
Piles—Inland	10	10	12	--	12	12	14	--
Marine	20	20	--	--	24	24	--	--
Poles	8	--	--	--	--	--	--	--
Ties, cross and switch	6	6	8	--	--	--	--	--
Tie plugs	6	6	6	--	--	--	--	--

[1] The amounts of preservative specified in the table are minima for the woods commonly used for the items listed. The requirement of higher retentions is justified for some woods, for pieces with large proportions of sapwood, and for pieces of large surface area in relation to their volume.

[2] In the case of the exceptional wood of a kind or character which precludes the retention of the minimum amount of preservative recommended, the treatment of the material should not be continued after it ceases to absorb preservative; that is, so-called treatment to refusal provides the maximum possible penetration and retention.

cell retentions shall be specified only when the maximum net retention is desired and it exceeds that obtainable by an empty-cell process.

In accordance with the Board of Direction policy of referring to recognized methods of analysis and tests instead of repeating them, delete pages 17–23 to 43 (401).

Pages 17–62, 63 and 64. Delete in their entirety and substitute the following in order to provide reporting recommendations conforming to adopted treating practice.

FORMS FOR REPORTING INSPECTION OF WOOD PRESERVING OPERATIONS AND RESULTS

1946

The recording and reporting of the detailed procedure in the treatment of wood is desirable; knowledge of what was done proves useful when seeking possible reasons for unsatisfactory results, provides information useful in developing treating methods, and supplies a check on whether or not the plant operator is adhering to the process specification.

The following forms supply spaces for data which should be submitted by inspectors of wood preserving as required. Their arrangement is a general guide which can be changed to meet the purposes of any railroad.

Form 1700 is a complete report of treating operations, with the absorption and retention of preservative based on gage or scale readings.

Form 1701 is a record of weights on which to base the retention of preservative.

Form 1700

Name of railroad

Name of wood-preserving plant — Location of wood-preserving plant

Name of inspector

Charge No.
Date
Type of material in charge
Number of pieces by sizes
Species
Degree of seasoning
Machining*
Cubic feet
Preservative
Process
Steam conditioning
- Time required to reach maximum temperature
- Time steamed at maximum temperature
- Maximum temperature
- Initial vacuum period
- Maximum vacuum

Heating in oil
- Heating period
- Maximum vacuum
- Maximum temperature
- Total condensation
- Total absorption of preservative

Treatment
- Initial air pressure
- Initial air period
- Pressure period
- Maximum pressure
- Maximum temperature
- Average temperature
- Maximum final vacuum
- Final vacuum period

Working tank readings
Working tank temperatures
Injection under pressure
Net retention
Total time of treatment
Number of borings
Percent conforming

* Incised, un-incised, rough, surfaced, worked, etc.

Form 1701

Name of railroad

Name of wood-preserving plant Location of wood-preserving plant

Name of inspector

Kind of wood
Kind of preservative
Total retention of oil at 100 deg. F.
Total retention of salts

Charge No.
Treating process
Date of treatment
Date of weighing

Tram No.	*Weight of empty tram*	*Weight of loaded tram before treatment*	*Weight of ties before treatment*	*Weight of loaded trams after treatment*	*Weight of ties after treatment*	*Number of ties*	*Gain in weight per tie*
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*		*Pounds*

Gallons or pounds of oil retained per tie.....
Percent of toxic salt in solution.....
Pounds of dry salt retained per tie.....

Report on Assignment 2

Service Test Records of Treated Wood

A. J. Loom (chairman, subcommittee), T. H. Friedlin, W. R. Goodwin, O. E. Hager, H. L. Holderman, R. S. Hubley, R. P. Hughes, O. C. Steinmayer, T. H. Strate, C. H. Wakefield.

The following report of special test records of ties on the Northern Pacific Railway is presented as information.

Northern Pacific—Hemlock Test Track

Designated by U. S. Forest Service as Project L–214

1800 Montana–Idaho hewed and sawed ties placed between Mile Post 120 and Mile Post 121 + 2350, westward main track, Missoula, Mont.

Treated at Paradise, Mont. with 80–20 creosote-coal tar solution, 6¾ lb. per cu. ft., Lowry process, and placed in track in 1910.

Summary of Ties by Species

Year	Western Hemlock	Western Larch	Douglas Fir	True Fir	Spruce	White Pine	Ponderosa Pine	Apsen	Total
1910	1072	436	166	102	18	2	3	1	1800
				Renewals					
1917	1								1
1924	1								1
1926	4								4
1928	43								43
1929	26	8	6	14	5				59
1932	49	9			3				61
1933	28	8	4	1	1				42
1934	43	18	1	6					68
1935	29	9	5	4					47
1936	42	11	3	1			1		58
1937	78	24	4	5	4				115
1938	72	24	1	6					103
1939	43	16	3	4	1				67
1940	80	22	5	8		1			116
1941	55	23	5	1		1			85
1942	48	16	2	8	1				75
1943	61	48	17	12	2				140
1944									0
1945	190	64	28	22				1	305
Total	893	300	84	92	17	2	1	1	1,390
% Renewed	83.30	68.81	50.60	90.20	94.44	100.0	33.33	100.0	77.22
Avg. Yrs. Per Tie	28.68	29.90	30.55	29.03	24.65	30.50	26.00	35.00	29.04

Six ties removed prior to 1928 were broken by derailment. Others all removed account decay hastened by damage from past derailments and mechanical wear at rail base.

77.22 percent renewals in 35 years.

Average life of ties replaced—29.04 years.

Report on Assignment 5

Destruction by Termites and Possible Ways of Prevention

Hermann von Schrenk (chairman, subcommittee), S. J. Buckman, W. F. Clapp, John Foley, F. W. Gottschalk, O. E. Hager, B. D. Howe, M. F. Jaeger, J. N. Roche.

This is a report of an inspection made on November 2, 1944, of the termite exposure test at Florissant, Mo. (1939–1944), and is presented as information.

In the Proceedings Vol. 34, 1933, page 483, your committee described a test carried out at Florissant, Mo. to determine whether various chemical compounds poured around 2 by 4 stakes driven into the ground would prevent attack by termites. Twenty-two compounds were used. A final report dealing with the results obtained was presented in 1938 (Proceedings, Vol. 39, 1938, page 290). Further references to this test and the conclusion that other tests should be undertaken, were made in the Proceedings, Vol. 40, 1939, page 505 and in Vol. 41, 1940, page 514. In this last report a number of compounds not hitherto tested were referred to, and a suggested plan for a second test installation was described. This plan was carried out on May 11, 1939, at which time 344 posts of southern pine 2 by 4's each 2 ft. long and pointed at one end were driven at Florissant until only 6 in. of their length was above ground.

For a proper understanding of the methods used and the reasons therefor, the following description is presented.

1. The purpose of the test was to try preventive treatments in three ways:

A. Impregnation of posts by a pressure process.

B. Dipping posts in the various solutions.

C. The use of solutions as soil poisons around the posts, using various strengths of solutions and various quantities poured either into "V" shaped trenches 2 in. wide at top and 3 in. deep or onto the ground.

2. While much information had been published on termite prevention, it was felt by the committee that there was very little if any information as to practical measures which could be used to obtain more or less successful protection. The committee therefore decided to do three things:

A. To select the compounds or solutions which seemed to hold promise.

B. To apply these compounds by injecting by pressure, by dipping them and by soil application.

C. To ask a number of the firms, both chemical concerns and wood preserving companies, who were promoting methods and substances for preventing termite attack to prepare and treat test posts, following specifications of the committee as to number of posts, arrangement of controls, labelling, and manner of reporting method of treatment, chemicals used and amount injected into each post. It was understood that companies treating posts with the substances in which they were interested would assume full responsibility for the treatments. Where the companies were not actually engaged in treatment, the committee arranged to have posts and solutions prepared under the direct auspices of the committee.

The committee endeavored to select the chemicals which experience had shown gave promise of successful prevention. Some compounds were tested about which little or nothing was known. They were included because the promoters made very definite claims and representations to railway companies. In each case the committee included their product only after careful consideration. Doubtless some products were omitted or overlooked. It should be understood that the committee assumed no obligation to test *all* compounds which had been advertised or suggested. It is believed that a very useful purpose was achieved by the cooperation, in the manner outlined, with commercial companies, from whom any railway could order salts, solutions or treatments. Where a company (and this happened in several cases) did not furnish chemicals or treat posts according to the committee's instructions, such chemicals or posts were rejected.

One other point should be mentioned. The committee in all cases followed the recommendations of every company as to how to use its product. If a company recommended that it be applied only by *pressure treatment,* no tests by soil poison application or dipping were made. On the other hand, if two or more methods of use were suggested, either verbally or by advertising, the committee used the methods advocated by the interested company. This will explain why in some tests only pressure impregnated posts were included; in others, pressure, dipping, and soil poison; in others, only soil poison; etc.

Method of Preparing Test Posts

The test pieces were each 2 ft. long—cut from southern pine (except sets treated with copper naphthanate, which included some Douglas fir and ponderosa pine). In all tests of this kind, *untreated control* pieces should be included, cut from the same pieces

of wood used for treatment. Your committee was most insistent that this proviso be followed for all compounds tested. This was done in the following manner, using pentachlorophenol as an example.

Six pieces of 8 ft. long 2 by 4's were picked from a pile at a St. Louis lumber company. These 2 by 4's were marked with copper (embossed) labels A–B–C–D–E–F. *Each* 2 by 4 was then cut into four 2-ft. pieces and these were marked A1, A2, A3, A4, and B1, B2, B3, B4 and so on for the C to F 2 by 4's. The treatment was then as follows:

All No. 1 pieces, i.e. A1–F1, were pressure treated.
All No. 2 pieces, i.e. A2–F2, were dipped.
All No. 3 pieces, i.e. A3–F3, were untreated controls.
All No. 4 pieces, i.e. A4–F4, were soil poison test posts.

The same procedure was followed with the whole series of tests, except when more than three treatments were applied. Then longer 2 by 4's were purchased and cut. For example, in the tests with trichlorbenzene, 16-ft. 2 by 4's were cut into 8 pieces each 2 ft. long. Pieces No. 1 and No. 4 were untreated controls. The main point was that there should be *untreated* pieces cut from the *same* 2 by 4's for each treatment. The pieces received from collaborators were carefully examined by the committee. If someone cut any old 2 by 4's into control pieces, such untreated and treated pieces were rejected, and another lot was treated.

Labels

All posts were provided with embossed copper labels before driving. On these labels the following was included:

1. Test number
2. Treatment symbol
3. Post number
4. Location number in row

Example for Celcure

Test number is 11
Treatment symbols are: A for controls
B for pressure
C for dipped
D for open tank
Post numbers are 1 to 12
Location coordinates are A1 to 64, B1 to 64, etc.

So a pressure-treated Celcure post might have the following label: 11–B–6–E17. One very important point about this method of labelling was that the inspection of posts could in no way be biased, because none of the inspecting party could tell what the individual posts were, what chemical was used, whether dipped, pressure treated, etc.

Selection, Preparation and Subsequent Care of Test Plot

A large tract of land, where termites were known to be very active was cleared. The soil consisted of a rich loam with high humus content. The plot was laid out in seven rows marked A to G. These were 4 ft. apart. The posts were driven 2 ft. apart in each row. The soil poisons were poured after the posts were driven.

While most of the posts were driven on May 11, 1939, there were several tests started at later dates; specifically:

Isco—posts driven April 20, 1940
Larvacide—posts driven April 20, 1940
Copper naphthanate—posts driven April 17, 1940.

As this report is being written arrangements are in progress for treating and installing 2 by 4 test posts treated with a number of compounds not hitherto included in the 1939 or 1940 installations.

The whole plot was left without any care. Weeds, blackberry bushes, etc. grew all over the plot. No attempt was made to clear away vegetation until October 25, 1944 when the whole area was cleared of all weeds and other growth to make inspection of the posts possible. It is now proposed to leave the plot alone again until such time as another inspection is planned.

Distribution of Posts in Test Plot

In the first tests at Florissant (See Proceedings Vol. 34, 1933, page 483) the posts with the same treatment were driven consecutively in a row. Objection was made, and properly so, that this was not a proper test because termites might not be present at all points in a plot of ground. It was suggested that the posts be scattered over the entire tract and far enough apart to prevent the results on any post being influenced by compounds used at adjacent posts. The following plan was therefore adopted for the 1939 and subsequent installations.

A total of 344 cardboard squares were cut. These were divided into 5 lots of 65, making 325 squares, and another lot of 19 pieces. It was planned to insert these posts in 5 rows of 65 each and one row of 19. These rows were marked respectively A, B, C, D, E, and F. Numbers were marked on the cardboard squares corresponding to the future position of the posts placed two feet apart in each of these rows; in other words the squares were marked from A1 to A65, and then from B1 to B65, etc. All of these cardboard pieces were put into a box and thoroughly shaken and mixed. The list of the test posts was then taken and a number was pulled out of the box for each of the individual pieces. The pieces were then driven in the location indicated by the individual cardboard squares; for instance, in the series for Pinola treatment. 1A, the first cardboard piece taken from the box was assigned to GL–1T. It read D21; that meant that GL–1T was the 21st post in the D row. Continuing this method of drawing with that series, E13 was drawn for GL–2T, E–33 for GL–3T, D10 for GL–4T, and B40 for GL–5T. The positions for the posts was in the manner of a lottery, insuring that there was no preference in favor of any piece in the field, and resulted in a very fair mixing distribution of each series of posts over the whole area.

All posts were driven into the ground so that only 6 in. showed above the ground line. After the driving, those which were to be protected by soil poisons, had the respective solutions promptly poured around them.

In order to be sure that the termites are actually working in the test plot, a considerable number of untreated pine stakes were driven all over the field, to be pulled up from time to time to see if any termites are in them. Incidentally, there was every evidence that termites are present in this area, as indicated by pieces of wood which had been lying on the ground, stakes, etc.

Cypress stakes, painted white and marked with black letters and numbers, were placed at the end of each row and along the sides. The rows were marked A, B, C, D, E, and F, and the posts along the sides were numbered 5, 10, 15, 20, up to 65.

After the completion of the work, a large chart was prepared showing the 6 rows and the positions of the posts in the test field.

A

Solutions Tested

For ready reference the tabulation lists the compounds and methods of application finally used.

Table of Compounds and Methods

Pinola
1A—Soaked
1B—Controls
2A—Poured*
2B—Controls

Trichlorbenzene
4A—Controls
4B—100 percent—poured*
4C— 80 percent trichlorbenzene—20 percent kerosine—poured*
4D—Controls
4E—50 percent trichlorbenzene—50 percent kerosine—poured*
4F—25 percent trichlorbenzene—70 percent kerosine—poured*
4G—10 percent trichlorbenzene—90 percent kerosine—poured*
9A— 500 cc. of 10 percent trichlorbenzene—90 percent petroleum—poured*
9B—1000 cc. of 5 percent trichlorbenzene—95 percent petroleum—poured**
9C—Controls
9D—2000 cc. of 5 percent trichlorbenzene—95 percent petroleum—poured**
9E—1000 cc. of 10 percent trichlorbenzene—90 percent petroleum—poured**
9F— 500 cc. of 5 percent trichlorbenzene—95 percent petroleum—poured*
9G—2000 cc. of 10 percent trichlorbenzene—90 percent petroleum—poured**

Coal-Tar Creosote and Kerosine
4H—50 percent of each—poured*

Antimite
5A—4 percent solution—poured*
5B—Controls

Wolman Tanalith U
6 —4 percent solution—poured*
15B—Controls

Zinc Chloride
7 —3.48 percent solution—pressure treated to refusal
5B—Controls

Pentachlorophenol (Permatol A)
8A—5 percent solution in fuel oil—pressure treated
8B—5 percent solution in fuel oil—dipped
8C—Controls
8D—5 percent solution in fuel oil—poured*

Hooker Solvent T
10A—Poured*
10C—Controls

Scafoil
10B—Two brush coats
10C—Controls
10G—Soaked 6 hours

Sharples No. 36 Mixture
10D—Poured*
10E—Dipped
10F—Controls

Celcure-Sol
11A—Controls
11B—Pressure treated
11C—Dipped
11D—Open tank process

Chromated Zinc Chloride
12A—Pressure treated—1.03 lb. per cu. ft.
12B—Controls

Alpha Nitronaphthalene
13A—Poured*
13B—Controls

Phenyl Mercury Oleate
13C—Pressure treated—0.098 lb. per cu. ft.
13D—Pressure treated—0.190 lb. per cu. ft.

Ascu
14A—Pressure treated—0.25 lb. per cu. ft.
14B—Controls
14C—Pressure treated—0.50 lb. per cu. ft.
14D—Controls

Wolman Salts—Tanalith U
15A—Pressure treated
15B—Controls

Larvacide (Chloropicrin)
16A—Poured*
16B—Controls

Isco Insecticide Spray
16C—Poured*

Copper Naphthanate
17A—Dipped
17B, C, E, G, and I—Pressure treated
17D, F, H, and J—Controls

Inspection

The posts were inspected November 2, 1944, after they had been in the ground approximately 5½ years. None of the AREA committee members was able to come to St. Louis, so the chairman enlisted the aid of the following: Dr. A. L. Kammerer and Mr. Trifon von Schrenk of von Schrenk and Kammerer, and Drs. Ira Hatfield and R. A. Kaberg of the Monsanto Chemical Company. The day was brilliant with sunshine. Rain several days previously made the soil soft, and the posts could be readily pulled, using a chain around the post and lifting with a crowbar. Each post was pulled and inspected and then reset and redriven at once. Three persons inspected each post, a fourth read the labels and a fifth recorded the inspection results.

In the following tabulation the results of the inspection are given in detail. The posts which failed entirely were laid aside and will be saved for a year under cover so that anyone who wishes to look at them may do so.

The posts were rated in the inspection report by the following symbols which have been used by other agencies making similar tests. They appear as column headings in the tabulations of inspection results.

* Poured into "V" shaped trenches around the posts, 2 in. wide at the ground line and 3 in. deep.
** Poured in a circle of 20 in. diameter around the posts.

O = No attack
S = Slight attack
M = Medium attack
H = Heavy attack
F = Failed entirely and removed

When the inspection was made there was now and then a post which could not be classed as "Slight attack," but which was rated as "Trace" by the inspection group. Notes on this "Trace" were kept for future reference. In order to get a wholly unbiased opinion some six of these "Trace" posts were sent to Dr. Thomas Snyder, senior entomologist, U. S. Bureau of Entomology, with the request that he advise how the committee should handle this situation. Dr. Snyder agreed that "Trace" was a proper notation, but he would simply keep a note to this effect and put such a post in the column "No attack."

In view of the fact that posts in the test plot were exposed to both *termites* as well as to fungi producing *decay,* it was necessary in the inspection to note both termite and decay manifestion by the following symbols:

T = Termite attack
D = Decay

Thus in the column "O" (No attack) the symbol "TD" means "No attack by termites" and "No attack by decay," or where the letter "T" appears by itself, for instance in the column "M" (Medium attack) this means "Medium termite attack," and if "D" appears in column "H," it means "Heavy decay attack" for the same post.

Celcure

1. Source—Celcure Southern Corporation and the Atlantic Creosoting Company, Savannah, Ga. The former company cut the posts and carried out the non-pressure treatments, while the latter did the pressure treatment.

2. Composition—Acid cupric chromate.

3. Treatment—

Dipped.—Posts were dipped in a 12 percent solution for 2 hours at air temperature.

Open Tank Process.—The treatment was carried out in an open tank with a charge with cross ties, for which ¾ lb. net retention per cubic foot was specified. The actual retention per post and per cubic foot was determined by weight before and after treatment.

Pressure Process.—Treated with pressure at 125 lb. for 3 hours following a preliminary vacuum.

Dipped 2 Hours Post No.	*12% Celcure Mixture* Retention Solution per Post lb.
D 1	0.219
D 2	0.203
D 3	0.281
D 4	0.198
D 5	0.281
D 6	0.172
D 7	0.094
D 8	0.140
D 9	0.156
D 10	0.094
D 11	0.156
D 12	0.231
Average	0.189

Open Tank Process—3% Celcure Mixture

Post No.	Net Retention of Solution Lb. Per Post	Lb. Per Cu Ft.	Net Retention of Dry Chemicals—Lb. Per Cu. Ft.
T 1	2.3906	32.05	0.962
T 2	2.3125	31.00	0.930
T 3	2.3125	31.00	0.930
T 4	2.6718	35.81	1.074
T 5	3.1719	42.52	1.276
T 6	2.7500	36.86	1.106
T 7	2.2813	30.59	0.917
T 8	2.7656	37.21	1.116
T 9	2.5156	33.72	1.012
T 10	2.6250	35.18	1.055
T 11	2.5938	34.77	1.043
T 12	3.0	40.21	1.206
Average	2.6159	35.08	1.052

Pressure Process—3% Celcure Mixture

Post No.	Net Retention of Solution Lb. Per Post	Lb. Per Cu. Ft.	Net Retention of Dry Chemicals—Lb. Per Cu. Ft.
VP 1	1.25	16.756	0.502
VP 2	1.0	13.405	0.402
VP 3	1.0	13.405	0.402
VP 3	1.2343	16.545	0.496
VP 5	1.625	21.783	0.653
VP 6	1.1718	15.708	0.471
VP 7	1.3125	17.594	0.528
VP 8	0.9218	12.357	0.371
VP 9	1.4843	19.897	0.597
VP 10	1.0156	13.614	0.408
VP 11	1.1088	14.863	0.446
VP 12	1.2968	17.383	0.521
Average	1.2017	16.109	0.483

A fourth set of posts (cut from the same 2 by 4's as the preceding 3 lots) were left untreated as controls (Labels C1–C12).

Results of Inspection

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
11A Celcure	C 1	A 45	----	----	T	D	Yes
	C 2	C 63	----	----	----	TD	Yes
	C 3	D 40	----	D	T	----	No
	C 4	B 56	----	----	----	TD	Yes
	C 5	C 34	----	----	----	TD	Yes
	C 6	A 2	----	----	----	TD	Yes
	C 7	F 5	----	----	----	TD	Yes
	C 8	A 47	----	----	----	TD	Yes
	C 9	D 8	----	----	----	TD	Yes
	C 10	C 9	----	----	----	TD	Yes
	C 11	E 44	----	----	----	TD	Yes
	C 12	B 54	----	----	----	TD	Yes

Pressure Process

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
11 B Celcure	VP 1	A 36	TD	----	----	----	No
	VP 2	B 26	TD	----	----	----	No
	VP 3	C 16	TD	----	----	----	No
	VP 4	B 1	TD	----	----	----	No
	VP 5	D 1	TD	----	----	----	No
	VP 6	E 17	TD	----	----	----	No
	VP 7	C 25	D	T	----	----	No
	VP 8	A 11	TD	----	----	----	No
	VP 9	F 3	TD	----	----	----	No
	VP 10	A 20	TD	----	----	----	No
	VP 11	E 27	TD	----	----	----	
	VP 12	C 11	TD	----	----	----	No

Dipped

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
11C Celcure	D 1	E 4	D	T	----	----	No
	D 2	C 6	D	T	----	----	No
	D 3	E 65	TD	----	----	----	No
	D 4	B 31	T	D	----	----	No
	D 5	C 64	TD	----	----	----	No
	D 6	D 45	TD	----	----	----	No
	D 7	C 19	D	T	----	----	No
	D 8	E 42	D	T	----	----	No
	D 9	C 52	TD	----	----	----	No
	D 10	B 55	TD	----	----	----	No
	D 11	A 10	D	----	T	----	No
	D 12	A 7	TD	----	----	----	No

Open Tank Process

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
11D Celcure	T 1	B 36	TD	----	----	----	No
	T 2	B 42	TD	----	----	----	No
	T 3	E 36	TD	----	----	----	No
	T 4	D 2	TD	----	----	----	No
	T 5	D 59	TD	----	----	----	No
	T 6	E 47	TD	----	----	----	No
	T 7	B 11	TD	----	----	----	No
	T 8	D 29	TD	----	----	----	No
	T 9	E 11	TD	----	----	----	No
	T 10	B 3	TD	----	----	----	No
	T 11	D 46	TD	----	----	----	No
	T 12	C 17	TD	----	----	----	No

Pentachlorophenol

1. Source—Monsanto Chemical Company, St. Louis, Mo.

2. Composition—5 percent solution of pentachlorophenol in light petroleum, Permatol A treating solution.

3. Treatment—Treatment was carried out at the laboratory of the Monsanto Company in East St. Louis. There were four sets of posts. Set 1 was pressure treated, Set 2 was dipped 3 min., Set 3 was untreated, Set 4 had 500 cc. poured onto the ground around the posts.

Set 1.—Pressure treated as follows:

Pieces MSA1–MSC1

Vacuum: 30 min., 25 in.
Pressure: 50 lb., one hour at 140°F.
Vacuum: 30 min.

Pieces MSD1–MSF1

Vacuum: 20 min., 25 in.
Pressure: 30 lb., one hour at 140°F.
Vacuum: 30 min.

Post No.	Net Retention of Solution		
	Grams Per Post	Lb. Per Post	Lb. Per Cu. Ft.
MSA1	870	1.92	2.56
MSB1	956	2.11	2.83
MSC1	529	1.17	1.57
MSD1	964	2.13	2.86
MSE1	926	2.04	2.73
MSF1	279	0.61	0.82

Set 2.—Posts dipped 3 min.

Post No.	Net Retention of Solution		
	Grams Per Post	Lb. Per Post	Lb. Per Cu. Ft.
MSA2	30	0.066	0.088
MSB2	32	0.070	0.093
MSC2	31	0.070	0.093
MSD2	52	0.115	0.153
MSE2	49	0.108	0.144
MSF2	51	0.112	0.149
Average	41	0.090	0.120

Set 3.—Posts MSA3–MSF3 were driven untreated for controls.

Set 4.—Posts MSA4–MSF4 had 500 cc. of the 5 percent solution poured into each of their trenches.

Results of Inspection

Pressure Treated

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
8A	MSA1	B 19	TD	----	----	----	No
	MSB1	A 50	TD	----	----	----	No
	MSC1	B 60	TD	----	----	----	No
	MSD1	C 45	TD	----	----	----	No
	MSE1	E 6	TD	----	----	----	No
	MSF1	B 16	TD	----	----	----	No

Posts Dipped

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
8B	MSA2	D 20	----	----	T	D	Yes
	MSB2	A 14	----	----	T	D	Yes
	MSC2	D 62	----	----	----	TD	Yes
	MSD2	D 14	T	D	----	----	No
	MSE2	C 39	----	T	----	D	Yes
	MSF2	E 39	----	T	D	----	No

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
8C	MSA3	C 46	----	----	----	TD	Yes
	MSB3	D 25	----	----	----	TD	Yes
	MSC3	D 18	----	----	----	TD	Yes
	MSD3	B 44	----	----	----	TD	Yes
	MSE3	B 5	----	----	----	TD	Yes
	MSF3	E 34	----	----	T	D	Yes

Preservative Poured on Ground Around Posts

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
8D	MSA4	E 62	----	----	T	D	No
	MSB4	D 7	TD	----	----	----	No
	MSC4	C 24	----	T	----	D	No
	MSD4	D 49	----	D	T	----	No
	MSE4	D 43	----	T	----	D	No
	MSF4	A 55	----	T	D	----	No

Phenyl Mercury Oleate

1. Source—E. I. DuPont de Nemours & Co., Grasseli Chemicals Department, Wilmington, Del.

2. Composition—Phenyl mercury oleate in mineral spirit solution.

3. Treatment—pressure treated with final retention of:

Post No.	Retention Lb. Per Cu. Ft.	Post No.	Retention Lb. Per Cu. Ft.
13–C–1	0.083	13–D–1	0.171
13–C–2	0.096	13–D–2	0.188
13–C–3	0.102	13–D–3	0.192
13–C–4	0.106	13–D–4	0.206
13–C–5	0.099	13–D–5	0.177
13–C–6	0.102	13–D–6	0.205
Average	0.093	Average	0.182

Result of Inspection

Untreated Control

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
13B	13-B-1	B 34	----	T	D	----	No
	13-B-2	B 41	----	----	----	TD	Yes
	13-B-3	C 42	----	----	----	TD	Yes
	13-B-4	B 65	----	----	----	TD	Yes
	13-B-5	C 8	----	----	----	TD	Yes
	13-B-6	A 15	----	----	T	D	Yes

Pressure Process

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
13C	13-C-1	D 6	----	TD	----	----	No
	13-C-2	C 2	D	----	T	----	No
	13-C-3	C 53	T	----	----	D	No
	13-C-4	B 43	----	----	T	D	Yes
	13-C-5	E 9	----	D	T	----	No
	13-C-6	C 56	T	----	----	D	No

Pressure Process

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
13D	13-D-1	D 47	T	----	D	----	No
	13-D-2	B 58	T	----	D	----	No
	13-D-3	A 63	D	T	----	----	No
	13-D-4	A 24	----	DT	----	----	No
	13-D-5	A 64	D	----	----	T	No
	13-D-6	E 3	----	T	----	D	No

Ascu

1. Source—American Creosoting Company, Louisville, Ky., treated by S. J. Buckman.

2. Composition:

0.25 lb. Ascu per cu. ft. of wood	*0.50 lb. Ascu per cu. ft. of wood*
1 part AS_2O_5 $2H_2O$	1 part AS_2O_5 $2H_2O$
3 parts $CuSO_4$ $5H_2O$	3 parts $CuSO_4$ $5H_2O$
5 parts $K_2Cr_2O_7$	5 parts $K_2Cr_2O_7$
500 parts water	250 parts water

3. Treatment—All specimens were weighed. After closing of cylinder, the solution was pumped into the cylinder at atmospheric temperature (about 21 deg. C. to 24 deg. C.) and pressure of 150 lb. per sq. in. was applied for 3 hours, after which the treated pieces were allowed to drip for 6 hours in a closed container from which significant evaporation could not take place. The specimens were then dried to within about 5 percent of their original airdry weight. The following retentions were obtained:

Specimens treated with about 0.25 lb. of Ascu per cu. ft. of wood

Post No.	Retention Lb. Per Cu. Ft.
14AS– 1T	0.25
14AS– 2T	0.23
14AS– 3T	0.28
14AS– 4T	0.25
14AS– 5T	0.25
14AS– 6T	0.28
14AS– 7T	0.21
14AS– 8T	0.26
14AS– 9T	0.24
14AS–10T	0.21
Average	0.25

Specimens treated with about 0.50 lb. of Ascu per cu. ft. of wood

Post No.	Retention Lb. Per Cu. Ft.
14AS–11T	0.54
14AS–12T	0.46
14AS–13T	0.69
14AS–14T	0.51
14AS–15T	0.56
14AS–16T	0.47
14AS–17T	0.62
14AS–18T	0.58
14AS–19T	0.52
14AS–20T	0.55
Average	0.55

Result of Inspection

Retention 0.25 Lb. Per Cu. Ft.

Series Mark	Post No.	Row	Symbol	O	L	M	H	Failed
14A	14AS-1T	D	39	TD	----	----	----	No
	14AS-2T	C	3	TD	----	----	----	No
	14AS-3T	B	46	D	T	----	----	No
	14AS-4T	F	8	D	T	----	----	No
	14AS-5T	E	24	TD	----	----	----	No
	14AS-6T	A	60	TD	----	----	----	No
	14AS-7T	B	21	TD	----	----	----	No
	14AS-8T	C	50	TD	----	----	----	No
	14AS-9T	E	46	TD	----	----	----	No
	14AS-10T	D	51	D	T	----	----	No

Retention 0.50 Lb. Per Cu. Ft.

Series Mark	Post No.	Row	Symbol	O	L	M	H	Failed
14C	AS–11T	C	10	TD	----	----	----	No
	AS–12T	C	58	TD	----	----	----	No
	AS–13T	E	5	TD	----	----	----	No
	AS–14T	D	31	TD	----	----	----	No
	AS–15T	D	16	TD	----	----	----	No
	AS–16T	D	48	TD	----	----	----	No
	AS–17T	C	36	TD	----	----	----	No
	AS–18T	D	19	TD	----	----	----	No
	AS–19T	B	47	TD	----	----	----	No
	AS-20T	A	30	TD	----	----	----	No

Untreated Control Posts

Series Mark	Post No.	Row	Symbol	O	L	M	H	Failed
14B	AS– 1C	A	52	----	----	T	D	Yes
	AS– 2C	C	29	T	----	----	D	Yes
	AS– 3C	D	57	----	----	----	TD	Yes
	AS– 4C	A	49	----	----	----	TD	Yes
	AS– 5C	A	48	----	----	----	TD	Yes
	AS– 6C	D	56	----	----	----	TD	Yes
	AS– 7C	B	18	----	T	----	D	Yes
	AS– 8C	C	21	----	----	----	TD	Yes
	AS– 9C	B	38	----	T	----	D	Yes
	AS–10C	E	15	----	----	----	TD	Yes

Zinc Chloride

1. Source—Von Schrenk and Kammerer laboratory.

2. Composition—Zinc chloride solution in water, 3.48 percent.

3. Treatment—open tank process. The posts were weighed before and after treatment. They were put into an open tank filled with the zinc chloride solution. The solution was heated beginning at 12:30 p.m.; it reached boiling point at 3:05 p.m. Heating stopped at 4:35 p.m. The posts were left in the cooling solution all night until 9:30 a.m. the next morning. The amount of zinc chloride retained was as follows:

Post No.	Solution Retained Lb. Per Post	Dry Salt Retained Lb. Per Cu. Ft.	Volumetric Absorption Percent
7–T4	3.21	1.543	64.8
7–U4	3.20	1.540	64.6
7–V4	2.53	1.354	54.8
7–W4	2.91	1.577	71.1
7–X4	3.37	1.620	72.9
7–Y4	3.29	1.580	71.3
Average	3.07	1.505	67.6

Results of Inspection

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
5B	T 2	D 17	----	----	----	TD	Yes
	U 2	E 26	----	----	----	TD	Yes
	V 2	C 14	----	----	----	TD	Yes
	W 2	D 58	----	----	----	TD	Yes
	X 2	B 35	----	----	T	D	Yes
	Y 2	A 41	----	----	----	TD	Yes

Open Tank Process

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
7	T 4	C 55	D	T	----	----	No
	U 4	C 26	----	TD	----	----	No
	V 4	B 7	D	T	----	----	No
	W 4	B 29	D	T	----	----	No
	X 4	C 32	----	TD	----	----	No
	Y 4	F 31	----	TD	----	----	No

Chromated Zinc Chloride

1. Source—The Grasselli Chemical Department of the E. I. DuPont de Nemours & Co. at Cleveland, Ohio, supplied 10 treated posts and wrote as follows May 23, 1939. "As our attitude toward zinc chloride and chromated zinc chloride has consistently been that these materials are not competitive with creosote for use in the ground against termite attack, I very much question whether a higher zinc chloride treatment than accorded your test specimens would have given or will give a better termite prevention treatment."

In view of the general interest in zinc chloride and chromated zinc chloride, and frequent recommendations by others than the Grasselli company, the committee decided to include the zinc chlorides and chromated zinc chloride treated posts in this test.

2. Composition—The salt used consisted of zinc chloride and sodium dichromate as provided for in the AWPA specification, i.e. zinc chloride—not less than 77.5 percent and sodium dichromate—not less than 17.5 percent.

3. Treatment—The posts were treated by the full-cell process and were weighed before and after treatment.

Treated Posts

Grasselli Post No.	Test Post No.	Percent Chromated Zinc Chloride	Chromated Zinc Chloride Retained Lb. Per Cu. Ft.
13	12A–T 1	2.78	0.97
23	T 2	3.22	1.13
33	T 3	4.19	1.47
32	T 4	2.46	0.86
53	T 5	4.12	1.44
63	T 6	3.36	1.18
73	T 7	2.06	0.72
83	T 8	2.86	1.00
93	T 9	3.04	1.06
103	T10	3.13	1.09
	Average		1.09

Results of Inspection

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
12B	GZCR-C 1	A 44	----	----	----	TD	Yes
	GZCR-C 2	A 16	----	----	T	D	Yes
	GZCR-C 3	B 25	----	T	----	D	Yes
	GZCR-C 4	D 42	----	----	T	D	No
	GZCR-C 5	B 32	----	----	----	TD	Yes
	GZCR-C 6	E 1	----	----	----	TD	Yes
	GZCR-C 7	A 1	----	----	----	TD	Yes
	GZCR-C 8	D 35	----	----	----	TD	No
	GZCR-C 9	E 60	----	----	----	TD	Yes
	GZCR-C10	C 60	----	----	----	TD	No

Treated Posts

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
12A	GZCR-T 1	E 23	D	T	----	----	No
	GZCR-T 2	F 1	----	DT	----	----	No
	GZCR-T 3	B 37	DT	----	----	----	No
	GZCR-T 4	D 54	D	T	----	----	No
	GZCR-T 5	C 61	D	T	----	----	No
	GZCR-T 6	C 35	DT	----	----	----	No
	GZCR-T 7	C 13	D	T	----	----	No
	GZCR-T 8	C 23	D	T	----	----	No
	GZCR-T 9	A 29	DT	----	----	----	No
	GZCR-T10	B 23	D	T	----	----	No

Wolman Tanalith U

1. Source—Wiles Chipman Lumber Company, St. Louis, Mo., supplied the posts and the treatment was done by Frost Lumber Industries, Inc. at Shreveport, La.

2. Composition—

	Percent
Sodium fluoride	25.0
Dinitrophenol	12.5
Sodium acid arsenate	25.0
Potassium dichromate	37.5

3. Treatment—One set was driven into the ground untreated. A second set was pressure treated with 0.356 lb. of dry salt per cu. ft. A third set had 500 cc. of a 4 percent solution of Tanalith U poured into the trench at the ground line.

Results of Inspection

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
15B	15B-1	F 16	----	----	----	TD	Yes
	15B-2	F 26	----	----	----	TD	Yes
	15B-3	F 35	----	----	----	TD	Yes
	15B-4	F 45	----	----	----	TD	Yes
	15B-5	F 50	----	----	T	D	Yes
	15B-6	F 60		Post Lost	----	----	----

4% Solution Wolman Tanalith U Poured into Trench Around Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
6	T-3	D 24	----	----	----	TD	Yes
	U-3	A 43	----	----	----	TD	Yes
	V-3	C 51	----	----	----	TD	Yes
	W-3	B 57	----	----	----	TD	Yes
	X-3	C 65	----	----	----	TD	Yes
	Y-3	B 50	----	T	----	D	Yes

Pressure Treated

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
15A	15A–1	F 20	T	D	----	----	No
	15A–2	E 31	D	T	----	----	No
	15A–3	A 19	----	TD	----	----	No
	15A–4	F 25	D	T	----	----	No
	15A–5	E 30	D	T	----	----	No
	15A–6	F 15	----	TD	----	----	No

Antimite

1. Source—Salt received from Antimite Company, St. Louis, Mo., Mr. Charles H. Bowen, Research Entomologist.

2. Composition—

	Percent
Sodium fluoride	33.3
Dinitrophenol	12.5
Sodium acid arsenate	54.2

3. Treatment—The Antimite Company recommended that 500 cc. of a 4-percent solution of antimite be poured into a trench around each post and that the soil be filled back and puddled so that it became saturated with the solution. This was done.

Results of Inspection

Untreated Control Posts

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
5B	T 2	D 17	----	----	----	TD	Yes
	U 2	E 26	----	----	----	TD	Yes
	V 2	C 14	----	----	----	TD	Yes
	W 2	D 58	----	----	----	TD	Yes
	X 2	B 35	----	----	T	D	Yes
	Y 2	A 41	----	----	----	TD	Yes

500 cc. of 4% Antimite Solution Poured into Trench Around Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
5A	T 1	B 10	----	----	----	TD	Yes
	U 1	B 59	----	T	----	D	Yes
	V 1	B 28	----	----	----	TD	Yes
	W 1	C 59	----	----	----	TD	Yes
	X 1	E 45	----	----	----	TD	Yes
	Y 1	C 49	T	----	----	D	No

Larvicide

1. Source—Innis Speiden & Co., Insecticide division, New York, N. Y., submitted nine posts.

2. Composition—Chloropicrin.

3. Treatment—The following treatment procedure was followed. Holes one foot deep were bored in the ground with a post hole digger. Six holes were assigned for treatment with Larvicide and three for untreated controls. They were labelled as follows: "16" representing the series; "A" representing posts treated with Larvicide; "B" untreated control posts. The posts were set in the order given in the paragraph headed "Results of Inspection."

After driving, 4 fluid ounces of Larvicide were poured around each post by Mr. J. F. Murphy (representing Innis Speiden & Co.) The holes were then immediately filled with soil so as to prevent loss of the gas by evaporation. Water was then poured around the posts to an inch in depth to assist in holding the gas in place. This series was placed at a coniderable distance from the other test posts so that the Larvicide would not contaminate the other soil poison tests.

RESULTS OF INSPECTION

Untreated Controls

Series Mark	Post No.	O	L	M	H	Failed
16B	B–2	----	D	----	T	No
	B-1	----	----	----	TD	Yes
	B–3	----	T	----	D	Yes
	B–5	----	----	----	TD	Yes
	B–6	----	----	----	TD	Yes
	B–4	Post lost	----	----	----	----

Treated Posts—Soil Poison Poured Into Holes Around Posts

Series Mark	Post No.	O	L	M	H	Failed
16A	A–1	----	----	----	D	Yes
	A–2	----	----	----	D	Yes
	A–3	----	----	T	D	Yes
	A-4	----	----	----	D	No
	A–5	----	----	T	D	Yes
	A–6	----	----	----	D	Yes

Isco

1. Source—Innis Speiden & Co., New York, N. Y.

2. Composition—Isco insecticide spray.

3. Treatment—The posts were treated with Isco in the same manner as was carried out with Larvicide, and by the same representative of Innis Speiden & Co. Four fluid ounces were used for each post.

INSPECTION

Untreated Controls

The untreated posts used for Larvicide control were cut from the same 2 by 4's as the Larvicide treated posts and the Isco treated posts; therefore they can serve as controls for both Isco and Larvicide treatments.

Treated Posts

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
16C	16C–1	F 11	----	----	----	TD	Yes
	16C–2	F 12	----	----	----	TD	Yes
	16C–3	F 13	----	T	----	D	Yes
	16C–4	F 21	----	----	----	TD	Yes
	16C–5	F 36	----	----	----	TD	Yes
	16C–6	F 43	----	----	TD	----	No

Sharples Solution

1. Source—Sharples Solvents Corporation, Chicago, Ill.

2. Composition—The company recommended two formulas as follows:

A. For ground treatment (dark colored materials)
- Crude Diamyl Phenol No. 65 ..... 1 part
- Dichloropentanes No. 40 ..... 2 parts
- Crude oil (crank case drainage or industrial fuel oil) 7 parts

B. Dipping or brush coating (light colored materials)
- Diamyl Phenol No. 105 ..... 1 part
- Dichloropentanes No. 14 ..... 2 parts
- Kerosine ..... 10 parts

3. Treatment—Three sets of posts were used, one set for ground treatment, one set for dipping in the preservative, and one set of untreated posts for control.

Soil Treatment.—These posts were driven into the ground and after driving "V" shaped trenches were dug around each post. Two liters of the ground treatment mixture marked No. 36 (see "A" in paragraph "Composition") were poured into the trenches around each post.

Dipping Treatment.—In this series the posts were dipped into the light colored solution (see "B" in paragraph "Composition.")

Results of Inspection

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10F	10A–6	E 58	----	----	----	TD	Yes
	10B–6	A 39	----	----	----	TD	Yes
	10C–6	E 48	----	----	T	D	No
	10D–6	C 48	----	----	----	TD	Yes
	10E–6	A 21	----	----	----	TD	Yes
	10F–6	C 47	----	----	----	TD	Yes

Preservative for Soil Treatment

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10D	10A–4	D 64	----	----	----	TD	No
	10B–4	A 9	----	T	----	D	No
	10C–4	C 40	----	T	----	D	No
	10D–4	D 15	T	D	----	----	No
	10E–4	E 14	----	----	----	TD	Yes
	10F–4	B 27	D	----	T	----	No

Dipping Mixture

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10E	10A–5	E 32	D	----	T	----	No
	10B–5	A 38	----	----	----	TD	Yes
	10C–5	E 22	----	----	----	TD	Yes
	10D–5	E 35	----	----	T	D	No
	10E–5	B 4	----	----	----	TD	Yes
	10F–5	A 59	----	T	D	----	No

Scafoil

1. Source—Scafoil Corporation, Houston, Tex.

2. Composition—Composed principally of Belgian coal-tar creosote.

3. Treatment—The following treatments suggested by the Scafoil Corporation were strictly followed by the AREA committee.

A. Give 2 brush coats, making sure that the first coat is dry before applying the second.

B. Soak 6 hours in preservative. (Post Series 10G, Nos. 10–A7 to 10–F7, soaked for 6 hours at room temperature and drained. Large quantities of the preservative must have been absorbed because they were very heavy.)

C. Leave one set of posts untreated as controls.

Results of Inspection

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10C	10–A3	C 7	----	----	----	TD	Yes
	10–B3	E 53	----	----	----	TD	Yes
	10–C3	A 32	----	----	----	TD	Yes
	10–D3	D 55	----	----	----	TD	Yes
	10–E3	E 19	----	----	----	TD	Yes
	10–F3	C 1	T	----	----	D	Yes

2 Brush Coats

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10B	10–A2	C 22	----	----	T	D	Yes
	10–B2	F 7	----	----	----	TD	Yes
	10–C2	A 61	T	----	----	D	Yes
	10–D2	D 5	----	T	----	D	Yes
	10–E2	D 52	----	----	----	TD	Yes
	10–F2	A 65	TD	----	----	----	No

Soaked 6 Hours

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10G	10–A7	E 52	TD	----	----	----	No
	10–B7	C 18	TD	----	----	----	No
	10–C7	B 61	T	D	----	----	No
	10–D7	D 11	TD	----	----	----	No
	10–E7	B 14	D	T	----	----	No
	10–F7	E 40	TD	----	----	----	No

Alpha Nitronaphthalene

1. Source—E. I. DuPont de Nemours & Co.—furnished as a solution marked "WP–13" containing 5 percent of "WP–13."

2. Composition—A 5 percent solution of Alpha Nitronaphthalene in an oil solvent.

3. Treatment—The DuPont Company recommended that 500 cc. of the 5-percent solution be poured around each post and this was done. A "V" shaped trench was dug around each post 2 in. wide at the ground line.

Result of Inspection

Untreated Controls

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
13	13–B1	B 34	----	T	D	----	No
	13–B2	B 41	----	----	----	TD	Yes
	13–B3	C 42	----	----	----	TD	Yes
	13–B4	B 65	----	----	----	TD	Yes
	13–B5	C 8	----	----	----	TD	Yes
	13–B6	A 15	----	----	T	D	Yes

Treated

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
13	13–A1	D 50	----	----	TD	----	No
	13–A2	B 62	T	----	----	D	Yes
	13–A3	A 8	----	----	----	TD	Yes
	13–A4	D 60	T	D	----	----	No
	13–A5	A 31	T	----	----	D	Yes
	13–A6	E 21	----	----	----	TD	Yes

Trichlorbenzene

1. Source—Hooker Electrochemical Company, New York, N. Y.

2. Composition—Liquid Trichlorbenzene—either 100 percent or diluted with kerosine.

3. Treatment—The soil poison applications were made by Von Schrenk and Kammerer as directed by the Hooker Electrochemical Company. In this test there were the following treatments:

Set 1. 4A–M1–S1, untreated controls for treatment Nos. 4B–M2–S2
4C–M3–S3

Set 2. 4D–M4–S4, untreated controls for treatment Nos. 4E–M5–S5
4F–M6–S6
4G–M7–S7

Set 3. 9C–A3–F3, untreated controls for treatment Nos. 9C–A1–F1
9C–A2–F2
9C–A4–F4
9C–A5–F5
9C–A6–F6
9C–A7–F7

Description of Soil Poisons Poured Around the Posts

Set No.	Quantity	Trichlorbenzene Strength (Percent)	
4	500	100	4B–M2 – S2*
5	500	80	4C–M3 – S3*
6	500	50	4E–M5 – S5*
7	500	25	4F–M6 – S6*
8	500	10	4G–M7 – S7*
9	500	10	9A–A1 – F1*
10	1000	5	9B–A2 – F2**
11	2000	5	9D–A4 – F4**
12	500	10	9E–A5 – F5**
13	1000	5	9F–A6 – F6*
14	2000	10	9G–A7 – F7**

*Poured into "V" shaped trenches around the posts, 2 in. wide at the ground line and 3 in. deep.
**Poured in a circle of 20 in. diameter around the posts.

The application of all of the various concentrations and amounts of liquid applied were all carried out in the same manner as directed by the Hooker Company. Where no "circle" was specified the liquids were poured into a 2 in. trench (at groundline) and 3 in. deep. Where certain circles of application were specified, a shallow depression in the shape of a circle was formed into which the liquid was poured as evenly as possible after the posts had been driven.

Results of Inspection

Set 1.—Untreated Controls (Applicable to Treatment Nos. 4B and 4C)

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
4A	4A–M1	E 63	----	----	----	TD	Yes
	4A–N1	B 45	----	----	T	D	Yes
	4A–O1	B 6	----	----	----	TD	Yes
	4A–P1	A 57	----	T	----	D	Yes
	4A–R1	D 3	----	----	----	TD	Yes
	4A–S1	D 53	----	----	----	TD	Yes

Set 4.—Soil Poison 500 cc. 100% Trichlorbenzene Poured Around Each Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
4B	4B–M2	C 41	TD	----	----	----	No
	4B–N2	B 8	TD	----	----	----	No
	4B–O2	B 39	TD	----	----	----	No
	4B–P2	B 2	TD	----	----	----	No
	4B–R2	D 32	TD	----	----	----	No
	4B–S2	E 28	TD	----	----	----	No

Set 5.—Soil Poison 500 cc. 80% Trichlorbenzene and 20% Kerosine Poured Around Each Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
4C	4C–M3.	D 36	TD	----	----	----	No
	4C–N3	A 56	TD	----	----	----	No
	4C–O3	A 4	TD	----	----	----	No
	4C–P3	D 4	TD	----	----	----	No
	4C–R3	A 23	TD	----	----	----	No
	4C–S3	B 48	TD	----	----	----	No

Set 2.—Untreated Controls (Applicable to Treatment Nos. 4E, 4F, and 4G)

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
4D	4D–M4	E 54	----	----	----	TD	Yes
	4D–N4	B 63	----	----	----	TD	Yes
	4D–O4	D 30	----	----	----	TD	Yes
	4D–P4	A 13	----	T	----	D	Yes
	4D–R4	A 40	----	----	----	TD	Yes
	4D–S4	E 50	----	----	TD	----	No

Set 6.—Soil Poison 500 cc. 50% Trichlorbenzene and 50% Kerosine Poured Around Each Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
4E	4E–M	A 22	TD	----	----	----	No
	4E–N	A 28	TD	----	----	----	No
	4E–O	C 30	TD	----	----	----	No
	4E–P	E 43	TD	----	----	----	No
	4E–R	A 5	TD	----	----	----	No
	4E–S	B 30	TD	----	----	----	No

Set 7.—Soil Poison 500 cc. 25% Trichlorbenzene and 75% Kerosine Poured Around Each Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
4F	4F–M6	A 3	TD	----	----	----	No
	4F–N6	B 15	TD	----	----	----	No
	4F–O6	D 44	TD	----	----	----	No
	4F–P6	E 55	TD	----	----	----	No
	4F–R6	F 25	TD	----	----	----	No
	4F–S6	C 37	TD	----	----	----	No

Set 8.—Soil Poison 500 cc. 10% Trichlorbenzene and 90% Kerosine Poured Around Each Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
4G	4G–M7	A 62	T	D	----	----	No
	4G–N7	B 22	TD	----	----	----	No
	4G–O7	A 34	----	----	----	TD	Yes
	4G–P7	B 51	TD	----	----	----	No
	4G–R7	B 20	T	----	----	D	No
	4G–S7	E 16	TD	----	----	----	No

Set 9.—Soil Poison 500 cc. 10% Trichlorbenzene and 90% Petroleum Poured Around Each Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
9A	9–A1	E 57	TD	----	----	----	No
	9–B1	E 37	TD	----	----	----	No
	9–C1	D 27	TD	----	----	----	No
	9–D1	C 31	TD	----	----	----	No
	9–F1	B 13	T	D	----	----	No
	9–F1	C 20	T	D	----	----	No

Set 10.—Soil Poison 1000 cc. 5% Trichlorbenzene and 95% Kerosine Poured Around Each Post in a Circle 20 In. in Diameter

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
9B	9–A2	E 18	T	----	----	D	No
	9–B2	A 12	T	D	----	----	No
	9–C2	D 33	----	----	TD	----	No
	9–D2	D 63	----	----	----	TD	Yes
	9–E2	A 17	TD	----	----	----	No
	9–F2	E 29	----	T	----	D	Yes

Set 3.—Untreated Controls (Apply to 9D–9E–9F–9G)

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
9C	9–A3	C 44	----	T	----	D	Yes
	9–B3	D 23	----	----	----	TD	Yes
	9–C3	D 38	----	----	----	TD	Yes
	9–D3	C 15	----	----	----	TD	Yes
	9–E3	D 34	----	----	----	TD	Yes
	9–F3	E 10	----	----	----	TD	Yes

Set 11.—Soil Poison 5% Trichlorbenzene and 95% Petroleum 2000 cc. Poured Around Each Post in a Circle 20 In. in Diameter

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
9D	9–A4	C 4	----	T	D	----	No
	9–B4	B 64	TD	----	----	----	No
	9–C4	A 35	T	D	----	----	No
	9–D4	C 33	T	D	----	----	No
	9–E4	B 12	T	----	----	D	No
	9–F4	B 52	T	----	D	----	No

Set 12.—Soil Poison 10% Trichlorbenzene and 90% Kerosine 1000 cc. Poured Per Post on Ground in Circle 20 In. in Diameter

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
9E	9–A5	F 4	T	----	D	----	No
	9–B5	C 57	T	----	----	D	Yes
	9–C5	A 53	T	----	----	D	No
	9–D5	E 20	T	D	----	----	No
	9–E5	D 12	T	----	----	D	Yes
	9–F5	E 49	----	----	T	D	No

Set 13.—Soil Poison 5% Trichlorbenzene and 95% Water 500 cc. Poured Close to Posts

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
9F	9–A6	A 18	T	D	----	----	No
	9–B6	C 62	----	TD	----	----	No
	9–C6	F 2	----	T	D	----	Yes
	9–D6	B 17	TD	----	----	----	No
	9–E6	A 27	T	----	----	D	Yes
	9–F6	E 38	T	----	D	----	Yes

Set 14.—Soil Poison 10% Trichlorbenzene and 90% Water 2000 cc. Poured Around Each Post in Circle 20 In. in Diameter

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
9G	9–A7	A 46	----	T	D	----	No
	9–B7	D 28	TD	----	----	----	No
	9–C7	D 37	T	D	----	----	No
	9–D7	C 27	TD	----	----	----	No
	9–E7	A 6	TD	----	----	----	No
	9–F7	E 61	T	----	D	----	No

Hooker Solvent T

1. Source—Hooker Electrochemical Company—New York, N. Y.

2. Composition—"Solvent T is a mixture of di, tri and tetrachlorbenzenes." The major constituent is trichlorbenzene. Hooker Electrochemical Company writes: "The tetrachlorbenzenes are even more permanent than the trichlorbenzene." "A mixture of the tri and tetrachlorbenzenes with the dichlorbenzenes would tend to prevent the complete evaporation of the dichlorbenzenes already known to have value in controlling termites."

3. Treatment—500 cc. of the concentrated liquid were poured into a trench dug around each post.

Result of Inspection

500 cc. Solvent T Poured into Trench Around Post

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10A	10–A1	A 51	TD	----	----	----	No
	10–B1	D 9	TD	----	----	----	No
	10–C1	A 42	TD	----	----	----	No
	10–D1	B 33	TD	----	----	----	No
	10–E1	D 13	TD	----	----	----	No
	10–F1	C 28	TD	----	----	----	No

Untreated Control

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
10C	10–A3	C 7	----	----	----	TD	Yes
	10–B3	E 53	----	----	----	TD	Yes
	10–C3	A 32	----	----	----	TD	Yes
	10–D3	D 55	----	----	----	TD	Yes
	10–E3	E 19	----	----	----	TD	Yes
	10–F3	C 1	T	----	----	D	Yes

Copper Naphthenate

1. Source—Socony Vacuum Oil Company—St. Louis, Mo.

2. Composition—Copper naphthenate dissolved in either Stoddard's Solvent or in light gas oil.

"200 S" series contains 15-percent copper naphthenate equivalent to 2-percent copper, dissolved in Stoddard's Solvent.

"100 S" series contains 7½-percent copper naphthenate equivalent to 1-percent copper, dissolved in Stoddard's Solvent.

"200 C" series contains 22-percent copper naphthenate equivalent to 2-percent copper, dissolved in light gas oil.

"100 C" series contains 11-percent copper naphthenate equivalent to 1-percent copper, dissolved in light gas oil.

3. Treatment—All posts, both untreated controls as well as treated posts, were received from the representatives of the Socony Vacuum Oil Company together with detailed statements (as prescribed by the committee as a requisite for placing any posts in this test) concerning species of wood, exact data as to treatment, kind of preservative used, retention of preservative in terms of pounds per cubic foot, and per post in terms of pounds of copper retained. The posts received were divided into 10 lots, each lot either given different treatments, or different preservatives, or untreated control posts. All posts were installed April 17, 1940.

Lot 1.—8 Posts of Douglas Fir Treated with Copper Naphthenate 100–C and 200–C by Dipping

Series Mark	Post No.	Method of Treatment	Hours	Compound Used	Retention Equivalent In Copper Per 100 Grams of Wood
17A	40–1D Cunaph	Dipped	8	Cu Naphthenate 100-C	0.35
	40–2D Cunaph	Dipped	8	Cu Naphthenate 100-C	0.31
	40–3D Cunaph	Dipped	3	Cu Naphthenate 100-C	0.20
	40–4D Cunaph	Untreated	0	----------	----
	40–5D Cunaph	Untreated	0	----------	----
	40–6D Cunaph	Dipped	3	Cu Naphthenate 200-C	0.49
	40–7D Cunaph	Dipped	8	Cu Naphthenate 200-C	0.81
	40–8D Cunaph	Dipped	8	Cu Naphthenate 200-C	0.76

Lot 2.—Pressure Treated with Copper Naphthenate 200–S

Series Mark	Post No.	Wood Species	Treatment	Retention—Grams of Solution Absorbed Per 100 Grams of Wood	Retention Equivalent in Copper Per 100 Grams of Wood
17B	17–B1	Ponderosa Pine	Untreated	----	----
	17–B2	Ponderosa Pine	Pressure	40.0	0.40
	17–B3	Western Spruce	Untreated	----	----
	17–B4	Western Spruce	Pressure	21.9	0.50
	17–B5	Douglas Fir	Untreated	----	----
	17–B6	Douglas Fir	Pressure	23.6	0.47

Lot 3.—6 Posts Southern Pine—Pressure Treated

Series Mark	Post No.	Treatment	Retention of Solution in Lb. Per Cu. Ft.	Equivalent in Copper—Lb. Per Cu. Ft.
17C	SV– 1	Cu Naphthenate 200-C	1.04	0.204
	SV– 2	Cu Naphthenate 200-C	1.72	0.338
	SV– 3	Cu Naphthenate 200-C	2.05	0.402
	SV– 4	Cu Naphthenate 200-C	1.68	0.330
	SV– 5	Cu Naphthenate 200-C	0.29	0.057
	SV– 6	Cu Naphthenate 200-C	0.23	0.045

Lot 4.—6 Posts Untreated Southern Pine 17D–SV–1C to SV–6C—Controls for 17C

Lot 5.—6 Posts Southern Pine—Pressure Treated

Series Mark	Post No.	Treatment	Retention of Solution in Lb. Per Cu. Ft.	Equivalent in Copper—Lb. Per Cu. Ft.
17E	SV– 7	Cu Naphthenate 100-S	1.77	0.254
	SV– 8	Cu Naphthenate 100-S	1.74	0.249
	SV– 9	Cu Naphthenate 100-S	1.03	0.148
	SV–10	Cu Naphthenate 100-S	1.55	0.222
	SV–11	Cu Naphthenate 100-S	1.09	0.157
	SV–12	Cu Naphthenate 100-S	1.17	0.168

Lot 6.—6 Posts Untreated Southern Pine 17F–SV–7C to SV–12C—Controls for 17E

Lot 7.—6 Posts Southern Pine—Pressure Treated

Series Mark	Post No.	Treatment	Retention of Solution in Lb. Per Cu. Ft.	Equivalent in Copper—Lb. Per Cu. Ft.
17G	SV–13	Cu Naphthenate 100-C	1.06	0.152
	SV–14	Cu Naphthenate 100-C	1.58	0.227
	SV–15	Cu Naphthenate 100-C	0.68	0.098
	SV–16	Cu Naphthenate 100-C	1.05	0.151
	SV–17	Cu Naphthenate 100-C	0.81	0.117
	SV–18	Cu Naphthenate 100-C	1.60	0.230

Lot 8.—6 Posts Untreated Southern Pine—17H–SV–13C to SV–18C Controls for Series 17G

Lot 9.—6 Posts Ponderosa Pine—Pressure Treated

Series Mark	Post No.	Treatment	Retention of Solution in Lb. Per Cu. Ft.	Equivalent in Copper—Lb. Per Cu. Ft.
17I	SV–19	Cu Naphthenate 100-S	0.011	0.0053
	SV–20	Cu Naphthenate 100-S	0.053	0.0254
	SV–21	Cu Naphthenate 100-S	0.055	0.0265
	SV–22	Cu Naphthenate 100-S	0.055	0.0265
	SV–23	Cu Naphthenate 100-S	0.024	0.0117
	SV–24	Cu Naphthenate 100-S	0.011	0.0053

Lot 10.—6 Posts Ponderosa Pine Untreated—17J–SV–19C to SV–24C Controls for Series 17I

Results of Inspection

Lot 1.—Douglas Fir Dipped in Copper Naphthenate, 100-C and 200-C and the Untreated Control

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17A	40–1D	G 25	TD	----	----	----	No
	40–2D	G 34	TD	----	----	----	No
	40–3D	G 22	D	T	----	----	No
	40–4D*	G 58	----	TD	----	----	No
	40–5D*	G 9	----	----	----	TD	No
	40–6D	G 3	----	D	T	----	No
	40–7D	G 41	TD	----	----	----	No
	40–8D	G 12	TD	----	----	----	No

Lot 2.—Fir, Spruce, and Ponderosa Pine Treated with Copper Naphthenate 200–S

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17B	17–B1	G 33*	----	----	D	T	Yes
	17–B2	G 7	TD	----	----	----	No
	17–B3	G 44*	----	----	----	TD	No
	17–B4	G 1	TD	----	----	----	No
	17–B5	G 38*	TD	----	----	----	No
	17–B6	G 20	----	----	----	TD	No

*=Controls

Lot 3.—Southern Pine Pressure Treated with Copper Naphthenate 200–C

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17C	SV–1	G 37	TD	----	----	----	No
	SV–2	G 45	TD	----	----	----	No
	SV–3	G 49	----	TD	----	----	No
	SV–4	G 2	TD	----	----	----	No
	SV–5	G 4	TD	----	----	----	No
	SV–6	G 19	----	D	T	----	No

Lot 4.—Untreated Southern Pine Posts—Controls for 17C

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17D	SV–1C	G 35	----	----	T	D	Yes
	SV–2C	G 53	----	----	T	D	Yes
	SV–3C	G 49	----	TD	----	----	No
	SV–4C	G 40	----	----	T	D	No
	SV–5C	G 4	TD	----	----	----	No
	SV–6C	G 61	----	D	T	----	No

Lot 5.—6 Pressure Treated Southern Pine Posts Using Copper Naphthenate 100–S

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17E	SV– 7	G 13	TD	----	----	----	No
	SV– 8	G 55	TD	----	----	----	No
	SV– 9	G 42	TD	----	----	----	No
	SV–10	G 5	TD	----	----	----	No
	SV–11	G 46	TD	----	----	----	No
	SV–12	G 10	TD	----	----	----	No

Lot 6.—6 Untreated Southern Pine Posts—Controls of 17E

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17F	SV– 7C	G 51	----	----	T	D	No
	SV– 8C	G 8	----	T	----	D	Yes
	SV– 9C	G 39	----	T	D	----	No
	SV–10C	G 21	----	----	----	TD	Yes
	SV–11C	G 32	----	----	----	TD	Yes
	SV–12C	G 60	----	----	----	TD	Yes

Lot 7.—6 Posts Southern Pine Pressure Treated with Copper Naphthenate 100–C

Series Mark	Post No.	Row Symbol	Lbs. Retained	O	S	M	H	Failed
17G	SV–13	G 15	1.06	TD	------	------	------	No
	SV–14	G 48	1.58	TD	------	------	------	No
	SV–15	G 29	0.679	TD	------	------	------	No
	SV–16	G 6	1.05	TD	------	------	------	No
	SV–17	G 26	0.813	TD	------	------	------	No
	SV–18	G 11	1.60	TD	------	------	------	No

Lot 8.—Untreated Southern Pine Posts—Controls of 17G

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17H	SV–13C	G 14	----	----	----	TD	Yes
	SV–14C	G 16	----	T	----	D	Yes
	SV–15C	G 62	----	D	----	T	No
	SV–16C	G 17	----	----	----	TD	No
	SV–17C	G 18	----	D	----	T	Yes
	SV–18C	G 23	----	----	----	TD	Yes

Lot 9.—6 Ponderosa Pine Posts Pressure Treated with Copper Naphthenate 100–S

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17I	SV–19	G 50	----	----	T	D	No
	SV–20	G 47	----	TD	----	----	No
	SV–21	G 24	TD	----	----	----	No
	SV–22	G 57	TD	----	----	----	No
	SV–23	G 30	----	TD	----	----	No
	SV–24	G 56	----	D	T	----	No

Lot 10.—6 Untreated Ponderosa Pine Posts—Controls of 17I

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
17J	SV–19C	G 54	----	----	T	D	Yes
	SV–20C	G 27	----	----	----	TD	Yes
	SV–21C	G 36	----	----	----	TD	Yes
	SV–22C	G 52	----	----	----	TD	Yes
	SV–23C	G 43	----	----	----	TD	Yes
	SV–24C	G 59	----	----	T	D	Yes

Pinola

1. Source—Glidden Company, St. Louis, Mo.

2. Composition—A product derived from southern pine by distillation and extraction, consisting largely of rosin and pine oils (dead oil) dissolved in "Pinap."

3. Treatment—Posts were soaked, i.e. submerged in a vat filled with Pinola for 24½ hours. The amount of liquid absorbed was as follows:

Post Mark	Gain in Weight Lb.
GL–1T–38	0.172
GL–2T–38	0.500
GL–3T–38	0.156
GL–4T–38	0.547
GL–5T–38	0.453

A set of untreated posts was cut from the same 2 by 4's and marked GL–1C–GL–5C.

Another set of posts was driven into the ground and 500 cc. of Pinola was poured around each post of the series marked 2A–GL6S–10S. Untreated control posts marked GL–6C–GL–10C were cut from the same 2 by 4's and driven into the ground untreated.

Results of Inspection

Posts Soaked in Pinola

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
1A	GL–1T	D 21	----	D	T	----	No
	GL–2T	E 13	TD	----	----	----	No
	GL–3T	E 33	D	----	----	T	No
	GL–4T	D 10	TD	----	----	----	No
	GL–5T	B 40	T	----	D	----	No

Untreated Posts—Controls for Series 1A–1T–5T

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
1B	GL–1C	C 38	T	----	----	D	Yes
	GL–2C	D 61	----	----	----	TD	Yes
	GL–3C	E 51	----	----	----	TD	No
	GL–4C	B 24	----	----	----	TD	Yes
	GL–5C	F 6	----	----	----	TD	Yes

500 cc. Pinola Poured Around Posts on Ground

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
2A	GL-6S	B 53	----	----	T	D	No
	GL-7S	B 49	----	T	----	D	Yes
	GL-8S	C 12	----	----	----	TD	Yes
	GL-9S	E 7	----	----	----	TD	Yes
	GL-10S	A 25	----	----	----	TD	No

Untreated Posts—Controls for Series B 6S-10S

Series Mark	Post No.	Row Symbol	O	L	M	H	Failed
2B	GL-6C	A 26	----	----	----	TD	Yes
	GL-7C	F 30	----	----	----	TD	Yes
	GL-8C	E 12	----	----	----	TD	Yes
	GL-9C	A 37	----	----	----	TD	Yes
	GL-10C	F 19	----	----	----	TD	Yes

Distillate Creosote—Kerosine

1. Source—Von Schrenk and Kammerer laboratory—St. Louis.

2. Composition—Distillate creosote + kerosine.

3. Treatment—500 cc. mixture of 50-percent distillate creosote and 50-percent kerosine was poured into a "V" shaped trench around each post. Another set of posts cut from the same 2 by 4 as the treated pieces was driven into the ground as untreated controls.

Results of Inspection

Posts with 500 cc. of Mixture—50 percent Distillate Creosote and 50 Percent Kerosine Poured Around Posts

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
4H	M 8	D 22	D	----	T	----	No
	N 8	A 58	----	----	----	TD	Yes
	O 8	C 43	T	----	----	D	Yes
	P 8	E 56	----	----	TD	----	No
	R 8	E 8	----	----	----	TD	Yes
	S 8	C 5	----	----	----	TD	Yes

Posts Driven Untreated as Controls—Posts Cut From Same 2 by 4's as Series 4H

Series Mark	Post No.	Row Symbol	O	S	M	H	Failed
4D	M 4	E 54	----	----	----	TD	Yes
	N 4	B 63	----	----	----	TD	Yes
	O 4	D 30	----	----	----	TD	Yes
	P 4	A 13	----	T	----	D	Yes
	R 4	A 40	----	----	----	TD	Yes
	S 4	E 50	----	----	D	T	No

Discussion

Emphasis is placed upon the fact that all tests involve only a small number of posts (6 to 12 in any one test). This should, of course, be remembered when the results are studied. As indicated in the beginning, these tests were undertaken largely to find out whether posts treated either by pressure, dipping, soil poison application, etc., by this or that chemical were protected against termite attack. The committee realized that ultimate life records would require many more individual posts. It is believed however that the results to date clearly indicate possible trends in protection. So for instance, if 6 posts in one test *all* remained without being attacked by termites during 5½ years, that might indicate that the compound, combined with the method of treatment used, is probably a fair risk and that one might venture to use such process and chemical with some assurance of increasing the life of wood in contact with the ground. The reverse

can of course be true for chemicals in combination with the treatment, which failed to protect the posts 100 percent, i.e. those which were attacked by termites to a greater or lesser extent. If wood is not protected *entirely* against termite attack, then it certainly cannot be considered as a material to be used on a large scale.

The committee will examine the remaining posts again after some years. Incidentally, all posts remain on the test tract except those completely destroyed by termites or decay.

Untreated Controls.—In every test, as explained in the beginning, each set of treated posts had a similar number of untreated posts called controls, cut from the same 2 by 4's as the treated posts. These untreated posts were driven in locations selected by lot, all over the test area. These untreated controls, with very few exceptions, were completely destroyed by termites and decay, so that they failed and in many cases fell over. The termite attack, judging by the appearance of the posts, probably took place soon after the posts were driven, i.e. probably within a year. The extra pieces of pine driven here and there were examined at frequent intervals and were found attacked during the first year in all cases. The universal termite attack at all points in the test area shows that this area was an excellent place for testing prevention of attack by chemical means because it gave assurance that resistance to termite attack could not be ascribed to absence of termites.

Conclusions

An analysis of the failures shows that chemicals applied as soil poisons, i.e. poured on the ground around posts, are not as effective as the same chemicals when applied by pressure or open tank methods.

The chemical compounds and methods of their application to the posts which to date have entirely prevented attack by termites as well as decay were:

Copper Naphthenate applied by pressure
Celcure applied by open tank (equivalent to pressure)
Ascu applied by pressure
Pentachlorophenol applied by pressure
Trichlorbenzene applied by pouring on ground around posts
Hooker Solvent T applied by pouring on ground around posts

Most of the posts attacked by termites were:

Untreated controls

Those treated by pouring solutions of various chemical compounds around the posts onto the soil—in other words, chemical compounds used as soil poisons.

Whether many of the chemical compounds applied as "soil poisons" would have protected the posts if such compounds had been forced into the wood by pressure is something which the committee did not investigate and which, accordingly, it cannot discuss.

The principal reason why the committee did not carry out many tests with posts treated by pressure is that at the outset the committee decided to follow the recommendations of the manufacturers who were advocating their products for termite control. With few exceptions they said, "Use our product as a soil poison."

Report of Committee 22—Economics of Railway Labor

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G. M. Strachan
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E. C. Vandenburgh
J. C. Wallace
H. J. Weccheider
Edward Wise, Jr.
C. R. Wright
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of work.

   No report.

3. Economies to be effected by more intensive supervision of gangs by supervisory officers.

   No report.

4. Labor economies derived from continuous welded rail in special locations.

   No report.

5. Economies that can be effected by reduction of clerical work through the elimination and simplification of reports.

   Final report, presented as information..... page 170

6. Labor economies to be derived by stabilizing roadbed by grouting methods.

   No report.

7. Methods of housing and transporting maintenance of way forces to reduce the use of motor cars and camp cars.

   Final report, presented as information..... page 172

8. Means of increasing or conserving labor supply for the duration of the war, advising the secretary currently of recommendations or practices that merit emergency publication by the AREA.

   No report.

The Committee on Economics of Railway Labor,
H. A. Cassil, *Chairman.*

AREA Bulletin 456, December 1945.

Report on Assignment 5

Economies That Can Be Effected by Reduction of Clerical Work Through the Elimination and Simplification of Reports

C. C. Haire (chairman, subcommittee), C. W. Baldridge, F. J. Bishop, J. C. Bradley, W. H. Brameld, W. T. Donoho, C. T. Gunsallus, R. C. Heckel, W. M. Jaekle, L. A. Loggins, Roy Lumpkin, F. R. Michael, H. E. Smith, W. H. Vance, J. C. Wallace, Edward Wise.

This is a final report, presented as information.

The clerical work of railway maintenance of way employees, in all its ramifications, is a problem that has been troublesome for many years and is rapidly growing worse in the railway industry. It is much accentuated by present day governmental requirements and wartime conditions. Clerical, accounting and related work of railway workers received its first impetus in 1907, when the first classification of accounts was promulgated by the Interstate Commerce Commission. In 1914, the present accounting classifications of the commission were issued which required more detail and imposed additional clerical and accounting effort. Subsequent revisions increased the burden and there was also superimposed on the accounting routines the valuation requirements, particularly Valuation Order No. 3.

The ICC accounting and valuation regulations are only a part of the government's requirements as there are many others, but those of the ICC have probably had the most profound effect on the clerical work.

In more recent times the problem has become more acute. The questions arising from employee relations, such as varying rates of pay, overtime, differentials between crafts, social security, unemployment tax, income tax (both state and federal), etc., have all resulted in more clerical work for railway forces.

It can readily be observed that there are two basic sources for clerical work:

1. Legitimate corporate requirements, to carry on the business of the carrier.
2. Demands of governmental bodies, such as federal, state and other agencies.

While the two basic causes are interrelated, there are phases of work in each that are not needed or required by the other. It appears correct to say that economies can be effected in each of these two classes and that corrective measures should be applied to reduce clerical effort in each—separately and in combination.

Agencies Responsible for Much Clerical Work

There is an almost endless field for the committee to investigate under this subject. It could delve into the question of the necessities and submit recommendations for modification of the meticulous distribution of labor and material costs to the numerous ICC primary accounts not needed for corporate purposes and which has a profound effect on the clerical work of maintenance of way forces, as well as all other railway employees. This moot question is hardly one on which the committee can submit specific suggestions other than to propose that appropriate measures be adopted to point out to the commission the desirability of further reduction in the accounting requirements.

Maintenance of Way Forces Burdened with Reports

The committee considers it advisable to confine its efforts to economies and simplifications that can be effected in engineering work—particularly maintenance of way forces. A study has been made to determine the practices of most of the major carriers

in the United States and Canada. A questionnaire circulated has brought forth a generous response with copies of the forms and records used by 40 railways having an aggregate road mileage of 213,934.

An analysis of the forms and records received from the various carriers, indicates the wide difference in viewpoint as to what is needed by a railway for corporate purposes and to comply with mandatory regulations of governmental agencies. One cannot help but feel that some roads are doing more than is needed and others possibly less, and that more uniformity is practicable regarding reports and records in the maintenance of way department. Some take the view that the railways should "clean their own house" before they raise any hue and cry about the severity of governmental regulations and this may be well applied to those roads which maintain records beyond what is needed to conform with ICC mandatory accounting regulations.

Personnel Forms and Records

Investigation by the committee of the clerical work being performed in the maintenance of way department, indicates that among the most burdensome matters are the numerous forms and records which must be prepared when hiring new employees. This condition has grown substantially in recent years because of the Railway Retirement and Social Security acts, the federal and state income tax requirement, especially in connection with the withholding tax, and the need to secure from employees a detailed personal history, medical examination, insurance, minor's release, etc. While the practice may vary on different railroads, yet the work of inducting a new employee into the service involves much detail; it is found in some cases that a laborer must sign his name at least 10 times.

The committee has studied the possibility of using a composite form that would embrace all forms and requirements so as to obtain only one signature from the new employee. It is, however, a most difficult task to get all departments, some of which have adopted their own special procedures, to agree to a combination of all the data on a single form, but maintenance of way officers should point out the advantages of a composite form even though it may change some office routines and records.

Conclusions

1. The first approach to a reduction in clerical work is to enlist the cooperation of the accounting forces so that simplified time, material and other reports can be redesigned to fit into a workable accounting routine. The question of using a daily or a monthly time reporting system and the employment of additional clerical help must be given proper weight as compared with the present methods of reporting, to determine if economies could be effected.

2. A revision of the time, material and other reports may be possible if an agreement is reached with the accounting forces to simplify the method of distribution of costs to record the minimum. A basis for this simplified distribution can be determined by appropriate time studies. By this principle, various maintenance of way operations can be studied and evaluated for various standard maintenance and construction operations. This plan requires the development in a scientific manner of unit costs and unit hours which can be used in making any logical accounting distribution. This principle is followed by most industries in determining the cost of manufacture and is practical if consistently studied and followed.

3. Modern accounting practices of the railroads do not require meticulous distribution, by primary accounts as in former years, as insufficient use is made of such statistics and costs, as accumulated in the accounts as they are today, to justify the effort and expense.

4. The efforts required to handle the personnel reports and records are unduly burdensome and the various departments of the railroad should endeavor to agree to a composite personnel form embodying all necessary data for inducting a new employee into the service. There is a duplication in the requirements of the Railroad Retirement Board, the Social Security Board, and the Bureau of Internal Revenue with respect to the withholding tax and this is likewise a matter demanding correction.

Report on Assignment 7

Methods of Housing and Transporting Maintenance of Way Forces to Reduce Use of Motor Cars and Camp Cars

J. S. McBride (chairman, subcommittee), E. J. Bayer, J. C. Bradley, E. J. Brown, F. G. Campbell, A. B. Chaney, C. G. Grove, J. G. Hartley, N. D. Howard, L. A. Loggins, J. B. Martin, E. H. McIlheran, A. K. McKeithan, Jr., F. R. Michael, W. H. Miesse, H. L. Miller, G. M. O'Rourke, E. C. Vandenburgh, H. J. Weccheider, Edward Wise, Jr., C. R. Wright.

This is a final report submitted as information.

The committee sent inquiries to a number of railroads as to their practice of housing and transporting maintenance of way forces. Replies were received from 49 roads in all sections of the United States and Canada, thus affording a good picture of present practices.

Housing

Method of Housing

A majority of the railroads replying (25) stated they have developed no method of housing other than camp cars. Twelve roads are using portable or knockdown houses; ten are using permanent or semipermanent buildings, as well as renting other buildings; and one road has a limited number of tents. Three of the roads using portable buildings also use some tents. Another road reports a portable house for a cook and dining facilities, but houses its men in camp cars. Two of the roads using portable buildings are also using automobile trailers to a limited extent for housing forces, one using them for housing signal men on special work and the other for two or three-man gangs.

Portable Houses and Tents

Of the 12 roads using portable or knockdown buildings, five have them at fixed locations only, five are using them for both fixed locations and for floating gangs, one prefers them for fixed locations but has used them for one floating gang, and one road uses them for floating gangs only. Tents, where used, are moved from place to place.

Generally, portable houses at fixed locations are used for section laborers, the occupancy ranging from one laborer and his family to as many as 16 men, with an average of 4 to 8 men. However, one road advises that it has portable buildings at a fixed location to house an extra gang of 30 men. For floating gangs, the portable houses are caring for 30 to 60-man extra gangs. Of the four roads that have made use of tents, only one reported the type and sizes of gangs housed in them, namely, floating gangs of 10 to 100 men.

The moving of portable houses when used for floating gangs presents a problem, but this has been solved on three roads by confining the widths of their units to from 9 to 11 ft. and moving them on flat cars. One road uses a work train in making these moves; another moves them by truck, a southwestern road endeavors to have extra units for kitchen and dining facilities and sets them up at new locations before the gangs are moved; while an eastern road with a 60-man extra gang provides a camp train to house the men while the portable buildings are being moved to the new location. None of the roads mentions the type of force used to remove the buildings and set them up in their new locations. One road states that it moves its tents by truck.

Six roads are using portable houses 16 ft. by 16 ft.; four use houses 9 ft. wide and 20 to 36 ft. long; one uses a building 11 ft. by 24 ft.; and another uses buildings 20 ft. wide and 48 ft. and 72 ft. long. The size of tent generally used is 16 ft. wide and from 16 ft. to 24 ft. long, although one road also uses tents 10 ft. by 12 ft. and 12 ft. by 24 ft.

The reported cost of these units varies considerably, even for units of the same size, this being due, no doubt, to differences in the types of construction involved. One road pays $300 for a 16 ft. by 16 ft. house, in sections; two other roads pay $350; and a fourth pays $450 f.o.b. Dallas, Tex. One midwestern road states that the same size house costs $500 plus $150 for erection, while a southwestern road advises that this size of house on foundation blocks, with a wood floor, and with sides and roof of plywood costs $450. One western road uses houses 9 ft. wide by 24 to 30 ft. in length, at an average cost of less than $500; and on another western road, 9-ft. by 36-ft. buildings cost $900 erected; while a third western road states that its buildings, 9 ft. wide and 20 to 36 ft. long cost $400 to build and $100 to erect. An 11-ft. by 24-ft. building used by a northwestern road cost $1070 per unit. On an eastern road using one building 20 ft. by 72 ft. for a bunk house, another building the same size for dining, cooking and commissary, and one building 20 ft. by 48 ft. for recreation, toilets, showers and commissary employes' quarters, all in connection with floating gangs, reports the cost of these buildings in place, as follows:

Buildings	$ 5,300
Unloading and erection	3,000
Grading and foundations	2,500
Insulation	1,500
Plumbing and fixtures	1,000
Drilling well and electric pump	1,000
Miscellaneous	500
Total	$14,800

A 16-ft. by 16-ft. tent with fly and wooden floor costs $275 in place on a midwestern road. On a Canadian road, a 16-ft. by 24-ft. tent, with bunks for 8 men and a separate fly and a knockdown board railing around the outside to which the tent roof and fly are attached—with a tent of similar size for cooking and serving meals to 10 or 12 men, cost $250. A western road purchased secondhand tents as follows: 10 ft. by 12 ft., $7.66; 12 ft. by 14 ft., $53.72; 16 ft. by 20 ft., $39.07; the price in each case was based on the condition of the tents at the time of purchase.

Fixed Houses

All the roads using the permanent and semipermanent types of buildings are using them to house section and other types of track gangs, one road also using them for signal and carpenter gangs. Six roads use these buildings at terminals exclusively, to house from 50 to 250 men. Two roads have these buildings at terminals and other strategic points to

house from 20 to 150 men. One western road uses them for yard and section gangs of 1 to 25 men. An eastern road uses them for 60 and 100-man gangs to supplement section and extra gangs.

Various types of construction were used in these buildings as follows: Condemned coach, baggage and box car bodies; wooden buildings; prefabricated buildings; tile and brick buildings; remodeled and converted old railroad buildings, originally constructed for other purposes, including an old enginehouse; rented buildings—in one case an old hotel. The cost and size of these buildings varied as much as the type of construction as is seen in the following examples.

An eastern road used a "U" type of frame building to house 120 men, the unit as a whole consisting of two bunk houses 25 ft. by 80 ft., with a joint toilet and wash room 20 ft. by 30 ft.; and a mess hall 20 ft. by 85 ft., with two wings, each 20 ft. by 25 ft. The approximate cost of this layout was $23,000.

Another eastern road used prefabricated frame houses 20 ft. by 56 ft., although kitchen and dining rooms are enlarged at camps housing over 100 men. Camps housing 80 men cost approximately $40,000; those for 250 men, approximately $100,000. This road states that it has maintained these permanent camps for more than 20 years.

A road in Illinois has constructed buildings for 20 to 50-man extra gangs. A 25-man bunk house is 20 ft. by 46 ft. A recreation house is provided at each camp, and, where 50 men are involved it is 20 ft. by 30 ft. The largest combination toilet, bath and laundry house is 25 ft. by 42 ft. The combination kitchen, dining room, storeroom and living quarters for the cook and foreman vary in size. The framework of these buildings was constructed of secondhand lumber, the walls are storm sheeted and covered with No. 2 grade asbestos shingles, and the roofs are covered with asphalt composition shingles. All of the buildings have concrete foundations and floors are electrically wired and have modern heating and plumbing. The average cost of these camps was approximately $10,000.

A belt railroad has constructed both frame and brick buildings at its terminals to house its track men. A modern brick building with 6300 sq. ft. of floor space, to house 90 men, was constructed in 1927 at a cost of $33,000.

Economics of Buildings

A majority of roads using portable houses report that they had to resort to them by reason of the labor emergency, in order to provide men where needed; two state that the cost is less than for camp cars or permanent buildings; one has used them because cars were needed for commercial service; another, to release camp cars for large road gangs; a third because of the economy of moving portable buildings from one location to another. With many of these roads the question of economy was not considered or had no bearing on the decision, and the arrangements were temporary because of the emergency.

Two southwestern roads and one northeastern road have used the fixed houses because of local conditions or because of the manpower situation. One of these states it does not intend to perpetuate these houses. Two eastern roads built them to house imported Mexican laborers. Two other roads have been using permanent houses for some years, one of them for 20 years. This latter road states that the matter of economy is not involved; the houses were provided in order to maintain the labor supply. One road in the midwest used these houses to care for colored laborers brought in from the south. One eastern road has used them only in two terminals, and another eastern road has built one house in a terminal to replace camp cars.

Three-fourths of all the roads using either the portable or fixed types of houses are still using camp cars. Roads making up the other one-fourth do not state definitely whether or not they are using camp cars. No definite labor economies from the use of

either type of housing were brought to the attention of the committee, although information in this regard was requested.

Transportation

Of the 49 replies received, 41 roads advise that they have used trucks and busses for transportation as well as motor cars; seven roads have used only motor cars; and one road did not state its practice definitely. Some of the roads using trucks and busses also make use of work trains for transportation, and one road having electric cars uses them for transportation.

As regards types of highway vehicles, trucks were favored—19 roads using only trucks, 6 using busses only, and 16 roads using both trucks and busses.

Type and Size of Gang

Trucks and busses are being used to transport practically every class of maintenance of way force, including section, extra, bridge, building, water service, signal and telegraph gangs. The force so transported varies from a single water service man to a 150-man extra gang used for rail laying and ballasting track.

Many roads make use of these to haul men, including high school boys, from larger cities to points where needed to augment or supplement regular and extra gangs. Because of the manpower situation, these men have been hauled as far as 30 miles by these trucks and busses. Some roads have hauled their men from permanent camps and others have used them in large terminals.

One western road is making a limited use of pick-up trucks for water service, for car repairmen and for bridge and building service.

A southern road is using ½-ton trucks for water service crews of one to three men, and 1½-ton trucks for bridge and building gangs of 8 to 15 men.

An eastern road has employed a survey corps personnel bus to haul an extra gang of 12 to 14 men, where the men formerly furnished their own means of transportation, which became impossible because of the shortage of autos, tires and gasoline. It also rented a truck equipped with benches to transport a carpenter gang of a foreman and 8 men to and from their camp cars in heavy traffic territory. This road also owns a ¾-ton utility truck which is used by signal and telephone maintainers, individually, as required. It also owns a 1½-ton truck with derrick, winch and seven-man cab, together with a 3-ton trailer, for a pole line construction gang consisting of a foreman and five men—the trailer being arranged to carry poles or a track car. In addition it has rented a 1½-ton truck equipped with power auger, winch and derrick for use by a crew of three men for digging pole and anchor holes, and a 1½-ton truck with winch and derrick, and a 2-ton trailer, for six men assigned to a specific pole line construction project.

Another road owns trucks which are used in its Chicago terminal for transporting bridge, building and water service forces and materials. It also has a 2-ton truck with inclosed metal body, windows and seats which is used by a district bridge gang of five men on one of its divisions.

A southern road reports that during the last few years when traffic became so dense (up to 60 or more trains per day) on its single-track line, it was necessary to find some means other than motor cars to transport its forces, and that it had resorted to trucks. It now uses 80 such trucks which are regularly assigned to certain section forces, extra gangs and in a few instances bridge and building forces. These trucks are used not only for transporting men but also to handle their materials and supplies.

A western road states that it has resorted to truck transportation for signal, telegraph and water service gangs in order to avoid congestion on the railroad.

A midwestern road was unable to obtain a normal track force on that part of its road near a large industrial center, and found it necessary to double-up its sections in order to maintain its track, and to resort to the use of busses to transport these section gangs to the points where work was to be done.

Several roads mention the difficulty of getting men to leave their homes to live in camps and one states that, if this continues, it may be necessary to locate gangs, including bridge and building gangs, in different towns and furnish them with truck transportation.

Uses Other Than Transporting Men

Most of the roads using trucks advise that, in addition to transporting men and equipment, the trucks also handle material, although some of these roads state that the trucks are seldom used for the latter purpose. Eight of the roads say that trucks are used only for transporting men and equipment while one road reports that trucks are used primarily for handling material, and that the transporting of men is incidental. Some of the roads using trucks and busses, in addition to handling men and equipment, use them to bring lunches to the men.

In some cases where trucks and busses are rented, the owners of the vehicles are employed in the gangs.

Ownership of Equipment

A majority of the roads using trucks only, own them, although many of them also rent trucks. Four roads do not state whether they own or rent their trucks. Two rent trucks and own none. A southwestern road uses some trucks of its highway transport company and rents other trucks. Most of the roads using only busses rent them, although one road owns some busses and rents others. Of the roads using both trucks and busses five both own and lease them, four own them, three lease them, two own trucks and lease busses, and two roads failed to give information on this point.

The rent paid for trucks varies. One road in the east pays $9 to $14 per day for a truck; another, $2.50 per hour, a third $8 to $20 per day. A fourth road pays $6 per day (size not stated), $80 per week for a 1½-ton truck with 2-ton trailer and $36.88 per day for a truck and earth borer for digging telegraph pole holes including gasoline, oil supplies, driver and operator. One western road pays 60 cents per hour where the railroad furnishes the driver, gasoline and oil, and $1.50 per hour where the owner drives and furnishes gasoline and oil. A northwestern road pays $9 to $14 per day. In the southwest, one road pays $4 per day without driver, and $10 to $15 with driver; another pays $6 to $15 per day, depending upon whether the railroad furnishes the driver or not and whether the truck is used for handling material during the day.

Two roads pay the same rent for busses as for trucks, i.e.. $9 to $14 per day. One eastern road pays 35 cents per mile for a bus seating 25 to 30 men, while a midwest road paid 25 cents per mile. It cost one eastern road regular commercial rates for a bus, and another paid $25 per day, depending upon the location of use and the length of the day. A midwest road obtained a bus seating 25 men for $15 per day, and a 20-man bus for $20 per day, where the driver also worked as a hand.

Economies of Highway Transportation

About 69 percent of the roads replying state that, for transporting their men there is economy in the use of trucks and busses as compared with motor cars; about 19 percent did not consider economy, or the saving was not the governing factor; and the balance state that there is no economy in their use. Those that were not influenced by

considerations of economy or that found no economy in the use of trucks and busses adopted them in an effort to provide forces in the face of war conditions, to avoid moving forces over tracks carrying heavy traffic, or to transport forces housed in buildings rather than move the buildings. Other roads that used this equipment because of war conditions report that they found it economical as compared with the use of motor cars.

The comments of a southwestern road on the economy of this means of transportation are as follows:

> While there are certain economies in the use of trucks for transporting labor when their use is part of a well designed plan of organization and operation, such economies may entirely disappear under the present urgencies. We have been required to haul men by truck as much as 40 miles in each direction each day. There are no economies in this and the only reason that it was done was because labor was not any nearer to the site of the work. Normally, we do not consider trucking labor over 8 or 10 miles. Generally, I would say that transporting labor by trucks is a practice which will be found more and more desirable in order to expedite the performance of maintenance work but the proper regulation of such transportation will have to await the coming of more satisfactory labor conditions.

One road in the middlewest says that all company owned trucks earn from 25 to 100 percent annually on the investment in them when full allowance is made for cost of operation, repairs, interest and depreciation. Another road in the same territory that rented busses because of war conditions, and that hauled men 15 to 30 miles each way, saved from 1½ to 2 hours per gang per day as compared with the use of motor cars for same purposes, resulting in a saving of 50 to 100 percent of the rent paid for busses, and at the same time there was a reduction in the hazard of accident.

Several roads advise that the use of trucks and busses reduces the time required by motor cars by 50 percent. Other roads estimate the saving in time from one to three hours per day, depending on the distance involved. The road that rented a truck equipped with an earth borer for digging holes for telegraph poles and anchors saved $1.50 per hole.

Some roads made use of trucks before the war and expect to expand their use. Other roads say that while war traffic made their use necessary, the economy realized will be sufficient to continue their use after business becomes normal. Many roads state that there are definite savings in their use, but that exact figures are not available. Some do not consider trucks desirable for regular section gangs that must inspect track, but find them satisfactory for gangs not inspecting track. One road prefers motor cars for short runs but trucks and busses where there is dense traffic.

Conclusions

1. The use of portable buildings has, in general, been brought about because of the labor shortage during the war, and this has also been true in many cases with respect to permanent and semipermanent buildings. In other instances permanent buildings are a part of the regular facilities for housing section and terminal gangs at points where such facilities are necessary to retain the required force.

2. A majority of the roads are using camp cars exclusively for housing floating gangs, and 75 percent of the roads using buildings are also using camp cars. No road reported that it is not using camp cars.

3. Very limited use is being made of automobile trailers to house small gangs.

4. Information relative to labor economies from the use of buildings to house maintenance of way forces is not available, but generally the matter of economy was not considered.

5. Trucks and/or busses have been used on a great many roads for transporting practically every class of maintenance of way forces, from one man up to 150-man gangs. Trucks are generally preferred to busses because they can be used for transporting material and equipment as well as men.

6. The use of trucks and busses has greatly increased during the war because of the necessity of transporting men to points where there is a shortage of labor, or to get forces off the track where traffic is dense. The results obtained by many roads have been such that they expect to continue the use of trucks and busses, and other roads plan to expand the use made of this equipment beyond that prevailing prior to the war.

7. Definite economies are to be obtained by using trucks or busses for transporting maintenance of way forces where the density of the traffic is such that excessive delays occur in the use of motor cars, and in transporting those forces that must travel long distances or that must make use of infrequent trains. Where this equipment is used, it should be a part of a well thought out plan of organization and operation. The economy will vary with conditions, but one road estimates its savings as 25 to 100 percent on 80 owned trucks after allowance is made for cost of operation, repairs, interest and depreciation.

Report of Committee 27—Maintenance of Way Work Equipment

C. H. R. Howe, *Chairman*,
C. M. Angel
R. M. Baldock
W. R. Bjorklund
G. E. Boyd
R. E. Buss
C. W. Engle
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J. L. Starkie
G. M. Strachan
M. C. Taylor
J. N. Todd
S. E. Tracy
Roy Wade
G. R. Westcott
F. F. Zavatkay
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revision..... page 180

2. Standardization of parts and accessories for railway maintenance motor cars.
   No report.

3. Manual of instructions for care and operation of maintenance of way equipment.
   No report.

4. Tie cutting machines.
   Final report, presented as information..... page 180

5. Machinery and tools for repairing maintenance of way equipment.
   Final report, presented as information..... page 182

6. Railway owned automotive equipment.
   No report.

7. Hoisting equipment.
   Final report, presented as information..... page 192

8. Diesel engines.
   Progress report, presented as information..... page 196

9. Electromagnets.
   Final report, presented as information..... page 199

AREA Bulletin 456, December 1945.

10. Oil filters.

Final report, presented as information..... page 202

11. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

No report.

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
C. H. R. HOWE, *Chairman.*

Assignment 1

Revision of Manual

Edgar Bennett (chairman, subcommittee), C. M. Angel, G. E. Boyd, N. W. Hutchison, R. K. Johnson, C. R. Knowles, Jack Largent, F. H. McKenney, C. E. Morgan, R. A. Morrison, A. J. Neff, G. R. Westcott.

Due to the restrictions in the use of copper during the war period it was necessary to amend Paragraph 1, Page 27–1, of the Manual, covering gasoline lines of copper construction in order to permit the use of alternate material, which was submitted to and adopted by the Emergency Committee representing the Board of Direction, June 22, 1942, and is currently shown on yellow sheet E–27–1 in the Manual, as follows:

1. Gasoline Lines
   Permissible alternate—approved flexible line with sediment bulb.

The flexible gasoline line has been so well received and used during the emergency period, and it has such a definite place of use in the future, either separately or in combination with copper tubing, that it is the recommendation of your committee that this amendment be permanently adopted for inclusion in the Manual as a subparagraph to Paragraph 1, "Gasoline Lines", on Page 27–1 of the Manual.

Report on Assignment 4

Tie Cutting Machines

F. H. McKenney (chairman, subcommittee), C. M. Angel, W. R. Bjorklund, R. E. Buss, G. H. Fair, C. R. Knowles, W. B. Lee, C. H. Morse, C. H. Ordas, T. M. Pittman, G. M. Strachan.

Your committee presents this report as information.

At present there is but one tie cutting machine available. The general purpose of the machine is to facilitate the removal of cross ties by cutting them into three pieces before removing them from track. The cuts are made between rails, the two end pieces are removed by pushing them out from under the rails, and the center piece is then lifted out, the general idea being to remove the tie with a minimum of ballast disturbance and to provide a solid bed for the new tie.

The machine is comparatively light, weighing less than 350 lb., and is mounted on a pair of double flanged wheels; it has a balance arm, with roller on its outer end, extending across to rest on the opposite rail. The machine can be assembled for either right or left hand operation. When spotted for cutting, the machine is held in position by means of clamps which grip the rail.

The power for the operation of the saw is supplied by a 3-hp. air-cooled gasoline motor equipped with magneto and mechanical governor.

The reciprocating action of the saw, which is swung from a vertically operating hand feed lever, is effected through a V-belt drive from the motor to a linkage assembly connected to the saw arm. The depth of cut and pressure applied is regulated by the manipulation of the hand feed lever. An attachment is provided on the machine for adjusting the length of saw stroke, which may be necessary in the case of unusually wide ties.

The saw blade itself consists of two inner cutting teeth, set so as to score either side of the cut, and an outer pair of raker teeth that are straight and somewhat shorter than the cutting teeth.

The machine is equipped with a saw sharpening grinder which may be connected to the motor by a V-belt. The grinding attachment is seated on the lift handle frame at the motor end of the machine.

One man operates the saw, while another prepares the ties to be sawed by digging away the ballast at the point the cut is to be made, which is just inside the tie plate. This is done with a pick or a special spud bar, or both, and is necessary to give clearance to the saw and to prevent it from dragging abrasive particles of ballast into the cut. These two men can easily set the machine off the track.

The saw may be used with section gangs of 8 to 10 men, or with tie gangs of 15 to 20 men. The average capacity of the saw is about 350 cuts per 8-hour day. For gangs of over 20 men, two saws should be used together. One road has used a tie gang of 60 to 70 men with four saws operating. Unless the saws are worked longer hours than the gang, a single saw will just about keep ahead of a 15-man gang.

The sole purpose of the machine is to facilitate the removal of the old ties, and reduce the amount of digging required to place the new tie and lessen the disturbance to the old tie bed. One road reports that it has not found the machine successful with hardwood ties nor in fine chatt or slag ballast. The ballast worked into the wood and too much time was lost changing worn saw blades. The saws work best with softwood ties and in gravel, cinders or light ballast. It is essential that a sufficient supply of sharp blades be on hand, as the machine will not operate successfully when blades become dull. One road has successfully heat treated the blades to secure greater hardness, which added about 20 to 40 percent to their life.

Report on Assignment 5

Organization, Machinery and Tools for Repairing Maintenance of Way Work Equipment

R. K. Johnson (chairman, subcommittee), Edgar Bennett, G. E. Boyd, F. L. Etchison, E. B. Harris, N. W. Hutchison, E. C. Jackson, W. A. Kingman, R. M. Leeds, W. H. Moore, R. A. Morrison, A. J. Neff, E. H. Ness, P. G. Petri, F. H. Rothe, J. C. Ryan, G. M. Strachan, M. C. Taylor, F. F. Zavatkay.

This is a final report, submitted as information.

In its investigation of this subject, your committee found it necessary to consider the matter of organization to be used in operating and maintaining the equipment. Therefore, a considerable portion of this report is devoted to the organization necessary for the proper application of machinery and tools in the repair of the work equipment.

The work equipment in use on the average railroad today for maintenance of way and structures work represents a very large investment. In order to secure the proper return from this investment, the equipment must be kept in serviceable condition and properly operated, it must be assigned to secure maximum use, and the right machine used for a given job.

The use of maintenance of way work equipment has increased tremendously in the past few years, but the organization and facilities to handle the operation and maintenance of the machines have not kept pace with this rapid expansion. As a result, much equipment has been damaged due to improper operation and maintenance.

Equipment is idle for long periods of time awaiting repairs. Inadequate repairs are made due to lack of facilities and trained men. Much idleness and abuse of the appliances have resulted from a failure to program the work and use the machines for purposes other than originally intended.

Repairs to the machines that are beyond the ability of the maintainer in the field can be more economically handled in a shop or shops especially equipped to repair maintenance of way work equipment. Special tools and machinery are needed to completely overhaul such equipment—the majority being similar to tools and machinery used in garages or repair shops operated by bus and trucking companies, or others specializing in the repair of gasoline and diesel engine operated equipment. Skilled mechanics of various crafts, trained in the repair to this type of equipment, are necessary.

Ordinarily the maintenance of equipment shops on railroads are equipped only to service locomotives and cars and do not have the special machinery and tools required for work on roadway appliances. By the same token, the mechanics employed in the maintenance of equipment shop are trained to service locomotives and cars and are not trained to repair maintenance of way work equipment. Usually when maintenance of way work equipment is handled in the mechanical department shops, such work is considered secondary to the handling of equipment for which that department is directly responsible. This entails delay in repairs to maintenance of way department work equipment.

It is desirable to have one system shop, or regional shops. Some advantages of the larger shops are:

1. Purchase and installation of facilities that cannot be justified in smaller shops scattered over the system.
2. Employment of skilled mechanics of various crafts which are not available nor justified in smaller shops.

A Well Equipped Machine Shop is Desirable.

3. The salvaging of usable repair parts is accomplished on a large scale.
4. The centralization of stock of repair parts for use in the shop and on line of road under one storekeeper, eliminating duplicate stocks and maintaining a low inventory.

Since the service received from any given piece of equipment is governed by the manner in which it is maintained and operated, your committee recommends, in the interest of maximum utilization, that a systematic organization, properly manned and fully equipped, be installed to supervise the operation and maintenance of work equipment in the field and in the shop. Such an organization could be set up along the same general lines as those of the signal department or water supply department now established on most railroads.

The placing of supervision of work equipment under a systematic organization does not necessarily mean a large additional expense. In many cases it would simply mean the coordination of existing personnel and facilities for only a small increase in outlay. Any additional expenses incurred in this manner will be more than off-set by better utilization and more efficient repair and operation of the appliances.

The size of the organization of a given railroad should be consistent with the amount of work equipment in service. The organization, your committee proposes, can be modified to suit conditions on any property. The shop machinery and tools for the adequate repairs of the appliances can likewise be modified.

The organization, a brief description of duties and a list of the shop machinery and tools follow:

Organization

Superintendent of Work Equipment

To avoid division of responsibilities and lost motion, the operation of and the repairs to work equipment, both in the field and in the shop, should be concentrated under the general direction of one man. He should have full authority to establish and enforce

Shop for Repairing Electrically Operated Work Equipment, Magnetos, Generators, Starters.

rules and regulations, and sufficient personnel to secure the desired results. He should report directly to the engineer maintenance of way or corresponding chief maintenance officer and should preferably have the same headquarters as this officer so as to expedite matters pertaining to maintenance, operation, repairs and the purchase of equipment. This will obviate unnecessary correspondence, duplicate files and records. The men in his organization and their duties are tabulated below:

Shop Supervisors

Report to superintendent of work equipment.

Should be furnished with shop or shops, fully equipped and properly manned, so as to make complete repairs to work equipment.

Maintain adequate stock of repair parts for use in shop and on line of road.

Inspectors of Work Equipment

Report to superintendent of work equipment.

Make periodic inspection in the field.

Make detailed reports as to operation and maintenance, violation of instructions or rules, improper assignment or handling of equipment.

Investigate equipment failures.

Keep close check on materials on hand in the field.

Check requisitions for new materials.

Assist in programming the shopping of equipment and securing necessary materials so that they can be on hand when the machine is shopped, thus reducing idle time of machine when it undergoes repairs.

Inspect new and repaired machinery when placed in service.

Assist in programming work to be performed on line of road by work equipment.

Assist in study of and development of new machines needed.

Maintenance of Way Work Equipment Undergoing Repairs.

Supervisors of Work Equipment

Report jointly to district engineer, division engineer or corresponding maintenance of way officer and superintendent of work equipment.

Have direct charge of mechanics or field maintainers, operators or others having to do with the operation and maintenance of work equipment.

Train operators and mechanics.

Program use of work equipment.

Secure materials for prompt repairs.

Arrange transfer of machines as necessary.

Enforce rules and regulations governing use of work equipment.

Road Mechanics or Maintainers

Should be assigned to definite territories with specific understanding as to their duties which should stress preventative maintenance.

Should be skilled mechanics thoroughly familiar with equipment to be maintained.

Should also be resourceful, as tools and facilities for making field repairs are of necessity limited.

Should make prompt repairs to disabled equipment.

Should see that operators handle equipment in accordance with instructions.

Should be furnished with tools necessary to make running repairs, and furnished with motor cars or trucks for transportation as needed. Lengths of territories should be governed by amount of equipment to be maintained and method of transportation.

Operators

The first responsibility for the care of maintenance of way work equipment rests with the operator who should report to the supervisor of work equipment as to the care and operation of the equipment.

He should be trained to make minor repairs to machines assigned to him.

Keep equipment assigned to him clean, properly lubricated, adjusted, and in safe and efficient operating condition.

Shop Equipped with Special Machinery and Tools for the Complete Repair of Gasoline and Diesel Engines.

This view shows crankshaft regrinding machine, line boring bar, cylinder boring bar, cylinder hone and metallizing equipment.

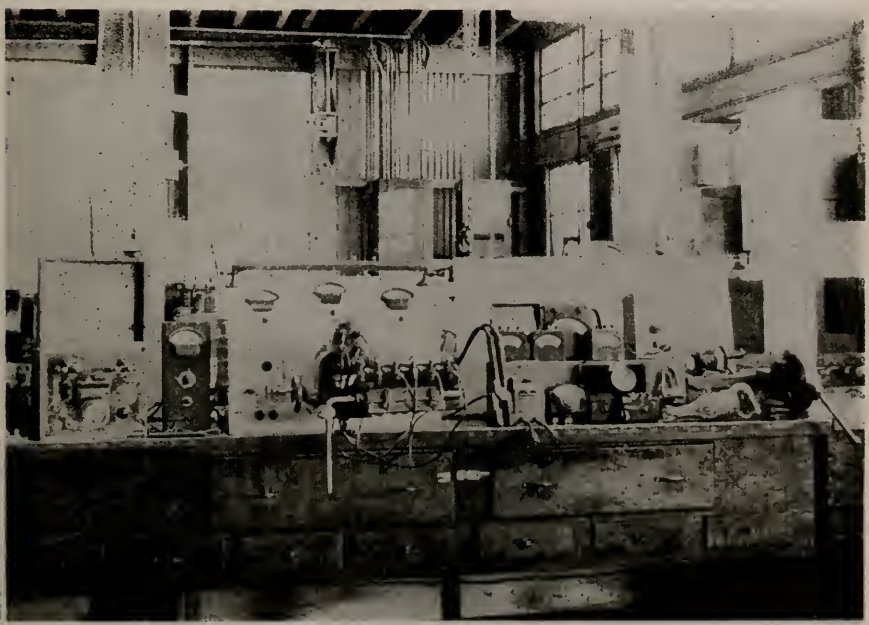
Electric Shop Tools and Equipment

D.C. ammeter (0 to 6 amp.) and (6 to 30 amp.)
D.C. voltmeter (0 to 150 volts) and (0 to 300 volts)
A.C. and d.c. tong tester (0 to 30 amp.) and (0 to 600 amp.)
Magneto meter
Magnet charger
Circuit analyzer set
Electric laboratory testing set for generators, regulators, starters, distributors, condensers, magnetos and coils.
Universal armature growler
Mica undercutter machine
Armature winding equipment
Armature dipping vat
Armature baking oven
Armature bearing and gear puller
Brush spring tension gage
Storage battery analyzer
Storage battery charger
Storage battery terminal cleaner
Storage battery cell tester (portable)
Hydrometer for battery acid test
Storage battery carrier strap
Varsol and safety cleaner vats
Starter Bendix repair tools
Set of thickness gages 10-in. length, range 0.002 to 0.050

Set of thickness gages 4-in. length, range 0.002 to 0.050
Set of ignition point wrenches
Complete set of socket and open end wrenches, $\frac{7}{16}$ in. to $1\frac{1}{2}$ in.
Soldering irons
Soldering iron furnace
Gasoline blow torch
Battery wax melting pot
Generator and starter pole shoe spreader
Generator and starter pole shoe screw remover
Dressing stones for armatures
Electric hand drill
Bench grinder and buffer

Gasoline Engine Testing and Reconditioning Equipment

Master tune-up analyzing set, including compression gage, tachometer, etc.
Vacuum gage
Ignition timing light
Engine running in or test stand equipped with dynamometer or other loading or braking device.
Spark plug cleaning and testing machine
Spark plug gap gage
Dial indicator cylinder gage



Special Tools and Machinery for Making Repairs to Electrical Equipment.

Crankshaft grinder, 22 in. by 84 in.
Main bearing line boring machine, 1¼ in. to 4 in.
Main bearing and connecting rod insert boring machine, 1 in. to 4 in.
Connecting rod bearing boring machine, 1 in. to 4 in.
Cylinder reboring bars, 2¼ in. to 9 in.
Cylinder hones, 2¼ in. to 6½ in.
Cylinder ridge reamers, 2¼ in. to 6½ in.
Crankshaft straightening equipment
Set of gasket punches, ¼ in. to 1 in.
Piston vise, 2¼ in. to 6½ in.
Piston pin bushing, reaming or honing machine, ½ in. to 2 in.
Connecting rod aligning machine
Valve refacing grinder, sizes ¾ in. to 3 in.
Valve seat hone and necessary seat cutters, 1 in. to 3 in.
Valve seat insert installing machine
Valve guide reamers, ¼ in. to ⅝ in.
Set of expansion reamers for bushings, (¼ in. to 2 in.) with line reaming extensions
Set of bearing scrapers
Valve grinders
Valve spring lifters
Piston ring compressors, 2¼ in. to 6½ in.
Set of "Easy out" (broken stud removers)
Set of stud removers
Riveting machine for clutch and brake lining

A Crankshaft Regrinding Machine.

Truck Equipped with Tools, Power-operated Machinery, and Material for Line-of-Road Repairs.

Fuel pump test rack
Valve spring tension tester
Tension wrench (cylinder head nut or cap screw)

Miscellaneous Tools and Equipment

Drills, 1/8 in. to 2 in. (64ths in. sizes up to 1 in.—32nds in. sizes over 1 in.)
Chucking or shell reamers, 5/8 in. to 2 in. (in 32nds in. sizes)
NC threading taps, 1/8 in. to 1¼ in. standard sizes
NC threading dies, 1/8 in. to 1¼ in. standard sizes
NF threading taps, 1/8 in. to 1¼ in. standard sizes
NF threading dies, 1/8 in. to 1¼ in. standard sizes
Pipe threading taps, ⅛ in. to 2 in. standard sizes
Pipe threading machine ⅛ in. to 2 in. standard sizes
Dial indicator testing set
Outside calipers, 4 in. to 18 in.
Inside calipers, 4 in. to 18 in.
Steel rule, 48 in.
Straight edge, 48 in.
Set of outside micrometers, 1 in. to 12 in.
Set of inside micrometers, 2 in. to 12 in.
Steel measuring tape, 75 ft.
Levels, 12 in. and 24 in.
Bevel protractor and combination square set, 18 in.
Screw clamps, 1 in. to 12 in.
Circular hole saws, 5/8 in. to 2 in.
Electric or air hand drills, 3/8 in. and ¾ in. capacity
Electric or air hand grinders, 8 in. grinding wheel
Electric light extensions
Set of spark plug threading taps
Set of gear pullers, 2 in. to 16 in.
Drive belt lacing machine
Tool-O-Meter for testing pneumatic tools 0 to 50 cu. ft., compressors 30 to 300 cu. ft. per min.

Electrical Tachometer Being Used to Check RPM. of Gasoline Engine.
Operates from secondary current of the ignition system.

Steam gage testing set
Set of carburetor repair tools
Set of ball bearing pullers, 1 in. to 6 in.
Hand bolt cutters and nippers, 24 in. and 36 in.
Pneumatic impact wrench (½ in. size)
High pressure pump for making hydrostatic test of tanks and boilers.
Bench vises, 4 in. and 6 in.
Socket wrenches and hand tools
Work benches
Paint spray equipment
Drying lamps
Hydraulic jacks, 2 to 50-ton
Floor jacks for moving trucks and buses
Automobile hoist for lubricating and light repairs
Power grease gun
Open fire furnace
Anvil and blacksmith tools
Oxyacetylene welding outfit
Electric welding outfit, 300 amp.
Power driven oxyacetylene cutting machine
Face plate

Small air hammer and riveting equipment
Small size stationary steam or air hammer
Lime box
Tool quenching vat
Annealing furnace
Sheet metal shearing machine, 60 in.
Flanging tools for copper tubing, 1/8 in. to 3/8 in.
Welding table
Soldering torch, oxyacetylene
Soldering acid gun
Radiator test tank and rubber ball test plugs
Air reduction valve for testing radiators
Complete set of body and fender straightening tools
Pipe wrenches, 8 in. to 36 in.
Set of body files
Tin snips, various sizes
Set of body jacks
Portable electric grinder
Electric or air fender hammer
Body solder heating torch and pot
Small babbit ladle
Preheating torch
Chain hoist as required
Brake drum lathe
Hydraulic press, 60-ton with ring gear riveting attachment
Radial drill press, 42 in.
Milling machine—necessary cutters and millers
Shaper, 24 in.
Engine lathe, 18 in. by 10 ft.
Universal tool grinder
Power hack saw
Bench drill, 3/4-in. capacity
Tool post grinder with internal grinding quills, 2-in. and 4-in. wheels
Metallizing equipment
Air compressor
Tire and tube repairing equipment
Wheel alining equipment (automotive)
Sewing machine and upholstering equipment
Taper pin reamers, No. 3 to No. 8 inclusive
Hydraulic brake cylinder hone
Hydraulic brake bleeder and filler tank
Hypressure steam cleaner and cleaning vat
Running-in testing machine for motor cars
Motor car wheel contour gage
Motor car wheel mounting gage
Motor car wheel tread and flange thickness gage

Wood Working Tools and Machinery

Band saw, 36 in.
Pony planer, 24 in.

Rip and cut off saw, size 16 in., with dado heads
Jointer, 12 in.
Electric hand saw, 8 in., with attachments
Electric portable sander, belt type
Electric portable sander, disc type
Standard set of carpenter tools
Glass cutters

Report on Assignment 7

Hoisting Equipment

R. A. Morrison (chairman, subcommittee), Edgar Bennett, G. E. Boyd, R. E. Buss, C. W. Engle, G. H. Fair, A. J. Flanagan, A. A. Keever, C. E. Morgan, C. H. Morse, C. H. Ordas, J. L. Starkie.

This final report is submitted as information.

Equipment for handling materials ranges from human arms and backs to cranes that will lift locomotives. Of these, the first is the least efficient, the most hazardous and in the long run the most costly. The following report attempts to describe types of mechanical hoisting apparatus used in the engineering and maintenance work of railroads.

The Lever

The fundamental principle of mechanics as applied to the workings of a lever is carried through in the various hook-ups of lines, cables, etc. to determine the amount of energy or power needed to lift a known weight.

The lever is a rigid bar movable about a fixed point called the fulcrum. The weight to be lifted multiplied by the distance to the fulcrum must equal the distance from the fulcrum multiplied by the pounds of effort to keep the force in balance. Any additional effort will raise the weight.

In hoisting machines, the example of the lever is best illustrated as applied to the hand winch or windlass. The diameter of drum governs the speed; the larger the drums, the greater the hoisting speed, but greater power is required and more line is necessary. The length of the turning handle determines the effort required; the longer the handle, the less effort needed.

Block and Tackle

Blocks threaded with fiber or wire rope are used for suspending scaffolds, raising objects and pulling or dragging heavy objects for short distances. When used to lift heavy materials, or to hold loads in suspension such as on heavy duty scaffolds, wire rope should be used.

Threading of the lines through the sheaves or pulleys in the blocks is most important. In blocks with multiple sheaves (3 or 4), the hauling end of line should lead from the middle sheaves of the blocks instead of from the outer ones. This involves a turn in the parts, but reduces the chance of slewing the blocks in their straps.

Tackles are of value not only for multiplying power but for applying power more smoothly and uniformly. A tackle consisting of 2 blocks with single sheaves (pulleys) has twice the power of a single block of one sheave. The power, or weight lifting capacity, increases proportionally as the number of sheaves increase. *Example:* A tackle made of 2

treble blocks has 6 times the power of a single block except for friction loss. A safe rule to compensate for the friction is to add 10 percent to the weight being lifted for each sheave through which the hauling lines pass. The speed and lifting distance is reduced in the same ratio as the power is increased.

Chain Hoists

Chain hoists may be used in locations where overhead cranes cannot be installed because of lack of headroom. Two portable types, differential and gear hoists, are available and may be used for handling heavy lifts at isolated spots where supports may be erected. Load sustaining parts of chain hoists should be made of steel rather than cast iron. Steel will withstand sudden shock better than cast iron and is much lighter in weight as compared with parts of equal strength. The chain should be made of the best quality of steel and welded.

Each hoist should be equipped with a braking device to lock the load automatically when the hoist is stopped.

Electric hoists are made in various sizes and capacities. They operate faster than hand-operated hoists and tend to reduce fatigue. Where compressed air is available, an air hoist can be used to good advantage, especially where the lift remains constant. The stroke of the air cylinder piston and cable arrangement will determine the hoisting distance of an air motor.

Supporting Devices

The supporting devices used with block and tackle, chain hoists and, to some extent, with portable electric hoists and power winches are as follows:

Tripod.—Three timber poles or steel pipe lashed securely at one end and erected with the other ends forming an equilateral triangle on the ground. The hoisting apparatus is suspended from the top. More poles can be added to give strength. The ends on the ground should be well placed and secured to prevent slipping.

Gin Pole.—Usually a timber pole anchored on the ground, standing at any desired small angle off the perpendicular and held in position by 4 guide wires leading from the top. The hoisting tackle is strapped securely to the top of gin pole.

A-Frame.—A timber or fabricated steel boom erected at an angle of about 45 deg., one end anchored on the ground, with the raised end held in position and supported by a line from the upright A-frame that is held in position by guys. The boom may be raised and lowered and swung in a small arc, the flexibility of movement being determined by the supporting lines.

Breast Derrick.—A timber frame work constructed similar to a door frame, supported slightly off the perpendicular to the top corners. The hoisting tackle is suspended from the top cross timber. The hauling lead is attached to a spool drum placed at the proper level above the ground between the upright timbers. The spool may be turned by the hand crank of a power winch.

Jib Crane.—A solid upright, mast or floor column with a horizontal boom extending from this support. The hoisting tackle is suspended from the end of this boom. When the boom is constructed so that it may be swung in an arc, it is often referred to as a wall crane.

Pillar Crane.—Used at permanent locations for handling heavy material. Usually constructed with a concrete base to which a steel column is anchored. The boom extends out from the base of column with a support cable extending from the end of the boom to the top of the column. The boom connections are made so as to permit movement

through an arc of 180 deg. and in some cases 360 deg. The hoisting winch is usually placed on the boom near the base. The winch is geared for hand operation or driven by an electric motor.

Derrick Car—Hand type.—Cars suitable for section and bridge and building forces are available. They are similar to a pillar crane, consisting of a steel column anchored to the center of a push car and supported by four steel legs extending from the center of the column to the deck of the car. The boom is constructed of 2 small I-beams, spaced and secured in the form of an elongated A, with sufficient room between the I-beams for placing the cables, pulleys and hoisting gears. The pulley and cable arrangement supporting the end of the boom is arranged for raising and lowering it. The boom operates through an arc of 360 deg. Clamps are provided for anchoring the car to the rails, and when this is done, the machine has a maximum capacity of 3000 lb. at a radius of 7 ft. from the center of the track. The lifting is done by hand through a crank-operated windlass.

Sand Hoist.—In the pneumatic engine sander, the dry sand is floated, so to speak, in a strong current of air from which it is separated at the delivery or outlet point. The air current enters the pipe conveyor by an injector-type nozzle while the sand enters the pipe by gravity. At the outlet, the air expands, the pressure is reduced, and the sand drops into the container. Before starting the air current, it is important to know that the air pressure is great enough to assure a continuous flow and thus minimize abrasion on the inside of joints, and reduce replacements of parts. All turns and bends should be reduced to a minimum and the air current kept in as straight a line as possible.

Steam or Air Rail Loaders.—Steam or air-powered rail loaders may have a single boom on one end of a car, or a boom on each end. The booms may be of timber or fabricated steel, anchored at the end of the car through a swivel joint. The boom end is guyed to a steel A-frame at the end of the car. The guides are flexible, so the boom end can be secured at the desired height and swing horizontally within the limits desired. This arc, however, cannot exceed 180 deg. The booms are removed and stored in the car when in transit or in storage. These cars are not self-propelled. Steam may be supplied from a stationary boiler mounted on the car or by a direct steam line from the work train engine.

Some machines are powered by air supplied from the locomotive compressors through a reservoir. By means of an operating valve the air is admitted into a long cylinder which contains the piston to which the hoisting cables are fastened. The stroke of the cylinder is multiplied in the hoisting line by a series of pulleys. On this type of machine the boom is swung manually.

The same type machine equipped with a self-contained air compressor is more satisfactory, and especially so when provided with air cylinders for horizontal movement of the boom. To be independent of a locomotive for air, is of considerable advantage, as it permits greater utilization and better planning of the work.

On construction jobs, such as repairs to bridge foundations where space is limited and the lift is not too great, a vertical air cylinder can be used for hoisting materials in buckets, the air being supplied through pipes connected with an air compressor some distance away.

Pile Drivers.—The standard on-track pile driver is mounted on trucks with standard wheels and bearings and is equipped with standard air brakes. It may be handled as a separate unit in regular trains. The essential features are a movable framework, hoisting engine and power plant.

The vertical portion of the frame consists of two uprights of wood or metal called the leads. The hammer works between these uprights. The working face of the leads should be made of metal. A horizontal section of the frame supports the control and operating mechanism, affords the operator a good view of his work and provides the necessary weight to counterbalance the load on the leads. This framework is mounted on the car so it can be stepped ahead and swung in an arc to provide the proper range for driving piles outside the rails, and it can be tilted for driving batter piles. The most modern machine is of all steel construction, can be swung in an arc of 360 deg., and is jointed so that the vertical frame can be folded back over the car when not in use. The hoisting machine is a power winch with cables carried to the top of the leads and thence secured to the drop hammer, which has a minimum weight of 3000 lb. The hoisting mechanism permits a quick release and a sudden drop of the hammer by force of gravity.

These units have a self-contained steam plant equipped with an upright boiler. Some units have space back of the boiler for fuel and water, while others carry their supplies in a small locomotive tender coupled to the pile driver car. A mechanism is provided for self-propulsion at a speed of 10 to 15 mph. Instead of a drop hammer a steam hammer can be placed in the leads, and connected to the steam plant through a flexible hose. The steam hammer can also be used without leads where conditions permit. In later models diesel and gas powered engines have been substituted for steam plants and machine power used for the drop hammer. Where hammers operated by steam or air are desired, an auxiliary boiler or air compressor may be used.

Pile driver leads are available as an attachment to the heavier locomotive cranes. The crane boom is secured to the leads at the top, and stability is afforded by introducing a horizontal A-frame between the bottom of the leads and the crane at the heel of the crane boom. The hoisting cables are run through a pulley at the top of the leads.

Off-Track Pile Drivers.—The crawler type cranes equipped with leads as described above are used to good advantage, where traffic is heavy or at points inaccessible to on-track machines. The hammer may be powered by an auxiliary steam plant or by compressed air.

On-Track-Cranes.—The hoisting machine most used on the railroads is the locomotive crane. It is essentially a pillar crane mounted on a turntable, carried on a short car of all-steel construction, with specially designed trucks having standard-gage wheels. The turntable permits the boom to operate at any angle in an arc of 360 deg. The power is furnished by a steam, gasoline or diesel engine. A mechanism is provided for self-propulsion. The booms are made of fabricated steel and are raised or lowered to the desired angle by lines from the power winch. These cranes range from the small model with a capacity of 5000 lb. on a 17-ft. radius, to the large wrecking cranes capable of lifting 250 tons on a 17-ft. radius. For maintenance of way work, the small crane is most adaptable. It can be used for working on the track rails, or it can be mounted on a flat car equipped with deck rails. The crane should be equipped with a boom (about 35 ft.) of sufficient length to extend over car ends and reach the center of a carload of material. On track they are used to a great extent in rail laying. Attachments that can be provided are small (⅓ to ½-cu. yd.) clam shell buckets, timber tongs, rail tongs, and rope and wire slings. They may be equipped with a generator for the operation of lifting magnets.

Similar hoisting machines mounted on crawlers are now available and thus offer greater usefulness, as they can do most of the work of an on-track machine without interfering with trains, thus eliminating delays in their operation. The modern machine is provided with gas or diesel power plants.

Diesel-Power Tractor With Hoisting Equipment

One of the newer machines consists of a power take-off winch mounted on a steel framework above a tractor. A steel A-frame boom is mounted on the side of the tractor, the heel of the boom being about 12 in. above the ground. Lines leading from one of the drums on the winch support the top of the boom and act as an auxiliary lift in raising and lowering the boom. The main lifting lead is threaded through blocks suspended from the top of the boom to the object being raised. The machine is counterbalanced by placing specially designed weights that fit in a rack on the side of the machine opposite the boom. While specially designed for laying pipes in trenches, it is readily adaptable as an off-track machine for laying rail and handling other maintenance materials. The machine has a lifting capacity of 10,000 lb. at 7 ft. from its longitudinal center line. Boom lengths vary from 12 to 20 ft. The boom is easily detached and blades can be attached for bulldozing.

Report on Assignment 8

Diesel Engines—Part I

C. R. Knowles (chairman, subcommittee), J. G. Hartley, N. W. Hutchison, E. C. Jackson, W. E. Kropp, Jack Largent, W. B. Lee, A. W. Munt, A. J. Neff, G. R. Westcott, F. F. Zavatkay.

This report is presented as information.

A discussion of the diesel engine and its characteristics, compared to other types of engines, makes it necessary also to include a discussion of other types of internal combustion engines as well.

Experiments in the development of an internal combustion or explosion engine were carried on before the advent of Watt's steam engine. These engines utilized various kinds of combustible and explosive materials, including gunpowder. However, it was not until 1794 that the first practical internal combustion engine employing the use of a flammable gas was developed, and it was 65 years later, in 1860, that the first engines of this type were used commercially for producing power. The theory of the cycle of operation to be carried out in the operation of an internal combustion engine, using gas as a fuel, in order to utilize the heat energy to the best advantage, was advanced by a French engineer some years later. This theory was based upon the operation of a single-cylinder, four-cycle engine, as follows: (1) Drawing in the charge of gas and air, (2) compression of the charge, (3) ignition of the charge followed by combustion and expansion, and (4) scavenging the gases from the cylinder. These principles still apply to engines of this type. In 1878 the Otto four-cycle engine was presented at the Paris Exposition and marked a revolution in the design of internal combustion engines.

The diesel engine was invented in 1892 by Dr. Rudolph Diesel, a German engineer and scientist. The general application of the engine in industry followed its exhibition in various types at the Munich Exposition in 1898, and it was introduced in this country about ten years later. The original engine, as well as practically all engines of this type, was of very heavy construction up to a comparatively few years ago. This was because of the high pressures in the original designs which necessitated heavier parts for the high stresses and bearing loads. The low speed of the engine also made it necessary to construct larger engines to produce the required horsepower. The original Diesel engines were

competitors of the steam engine and in many instances displaced them in the larger power plants. Thus it was nearly 40 years after the diesel was originally designed before it became an important source of power in trains, tractors, trucks and other automotive equipment, as well as for other comparatively small power plants. Today, diesel engine speeds of 1600 rpm. and cylinder bores of 3¾ in. are not uncommon. This compares with speeds of 200 and 300 rpm. and cylinder bores of 8 in. and upward, of 10 years ago.

Gasoline Engines

Gasoline engines as the name would imply are primarily designed to use gasoline as a fuel, although some have been converted to oil burning engines by the addition of attachments to permit of burning kerosene and low grade oils, and in some few instances they have also been converted to the use of gas as a fuel. Gasoline engines of the single-cylinder, four-cycle type were used extensively in railway water service for many years and a large number of them are still in service. More recent installations have been multiple-cylinder engines of both the two-cycle and four-cycle types. New installations have been confined largely to standby units and temporary service. They are used extensively for operating portable pumps. The majority of the earlier engines were of the horizontal type and many were provided with make-and-break ignition. Their operation was not always reliable and the maintenance was high, and with few exceptions they have been replaced with more modern engines or other types of power.

Semi-Diesel Engines

Oil engines commonly used for pumping at railway water stations are chiefly of the semi-diesel type which is a modified form of the full diesel. In these engines the oil is injected as a solid and as with other types of internal combustion engines, they are governed by throttling the oil supplied to the cylinder. In most of these engines ignition is accomplished by means of a hot tube or surface heated by a blow-torch before starting, the heat being maintained by the successive explosions. Another type of semi-diesel engine employs spark-plug ignition in which a gasoline primer is used. A small charge of gasoline is sprayed into the air intake manifold when starting; after the engine is started it operates on fuel oil which is also ignited by the electrical spark.

Diesel Engines

The full diesel engine is essentially a high compression engine in which the temperature of the air at the compression end of the stroke is high enough to ignite the fuel and produce continuous combustion. As in the gasoline engine, the heat or combustion cycle can be completed once every revolution in the two-cycle engine or once every two revolutions in the four-cycle engine. Two methods of injecting oil into the combustion chamber are employed. Air-injection and solid-injection. The air-injection system employs a multi-stage air compressor, which delivers the injection air at pressures ranging from 800 to 1500 lb. per sq. in. The solid-injection method does not require an air compressor, the oil being injected by a plunger type fuel pump which forces definite quantities of oil through the atomizing nozzles at high pressures, frequently in excess of 10,000 lb. Both methods atomize the oil either by means of small spiral grooves in the injection nozzle or through very fine holes (about 0.016 in. diameter).

Cost and Weight of Gasoline and Diesel Engines

It is difficult to make a direct comparison of the weights of gasoline and diesel engines. A builder of gasoline engines makes the claim that the weight of the average diesel engine is 51 percent greater than that of the average gasoline engine, while a diesel

engine manufacturer insists that the difference is only 28 percent. Assuming that the difference is the mean of the two figures given above, leads to a figure of about 40 percent, or a ratio of 1.40 to 1. However, any substantially correct figure as to the weight per brake horsepower necessitates a direct comparison between engines of the same size and the same cycle of operation.

The same principle applies to the comparative cost. While it is admitted that the diesel engine is a more expensive unit than the gasoline engine, the size of the engines and the quality of the materials must be given consideration in arriving at the cost per brake horsepower. The smaller the engine, the greater the difference in cost. It is estimated that in very small units, from 5 to 10 hp., the cost of the diesel engine may be from 2½ to 4 times the cost of the gasoline engine of the same horsepower, while with large units, the cost may be more nearly equal. In every case a direct comparison must be made between two units of like capacity to arrive at the relative costs, as a blanket statement to cover all conditions would be misleading, to say the least.

Cycle of Operation

The relative merits of the four-cycle and the two-cycle diesel engine comprise a controversial subject. Advocates of the four-cycle engine stress its greater economy in fuel consumption, together with the longer life and lower maintenance costs because of the heavier construction and general overall efficiency of the four-cycle engine. The question of weight per brake horsepower is an important factor in automotive equipment and is perhaps the deciding factor in selecting an engine which must be moved from place to place. In this the two-cycle supporters appear to have a convincing argument. They point to the diesels used in the high-speed streamlined trains, more than 90 percent of which are powered by two-cycle engines. On the other hand one of the largest manufacturers of automobiles and motor trucks is using a four-cycle diesel engine successfully.

Without taking sides with either, it may be said that both the two-cycle and the four-cycle diesel engines have a very definite place in the operation of equipment as used in railway maintenance of way.

Fuel Injection

Diesel engines are of both the air injection and solid or mechanical type injection, although the majority are of the solid injection type. In the latter type a high pressure pump is used to inject the fuel. These pumps are of many different types; each pump measures the exact quantity of fuel to be delivered to each cylinder. They force the oil into the cylinders at pressures of from 3000 to 20,000 lb. per sq. in. These high pressures are necessary to force the oil against the high compression pressures. The oil is injected into the cylinder through spray nozzles which break it up into fine particles. Precombustion chambers are generally used in which the oil is preheated to the burning point before passing into the cylinder as it expands. The delivery of the fuel is so timed that it enters the cylinders just before the piston reaches the top of the compression stroke where it is ignited by the heated air, which is the diesel principle of compression ignition. Dry air at a temperature of 60 deg. F. will attain a temperature of 1050 deg. F. when compressed into one fifteenth of its volume as free air. While diesel fuel oils ignite at various temperatures, practically all will ignite below 1050 deg. F.

Starting the Engine

Diesel engines are started in much the same manner as other internal combustion engines. Manual starting is possible with the smaller engines under 10 hp., but because of the higher compression larger engines must be started mechanically. Large stationary

engines are usually started by compressed air, some are provided with small gasoline engines, but the most popular and widely used means of starting the diesel engines as used in automotive service, is an electric starter similar to that used with automobiles and trucks.

Report on Assignment 9

Electromagnets

C. E. Morgan (chairman, subcommittee), C. M. Angel, W. R. Bjorklund, C. W. Engle, G. H. Fair, C. L. Fero, A. A. Keever, W. E. Kropp, F. H. McKenney, E. H. Ness, F. H. Rothe, J. C. Ryan.

Your committee presents this final report as information.

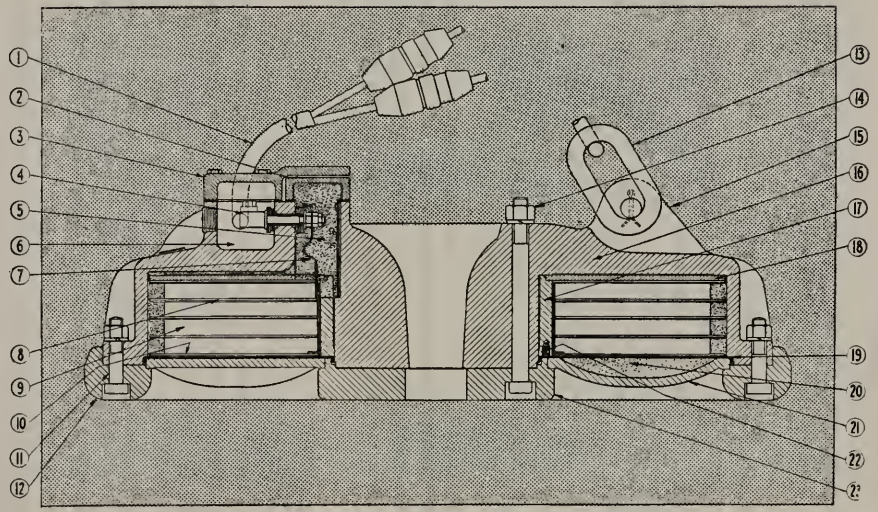
The development of the electromagnet as a weight lifting device is the result of the application of certain fundamental natural laws to man-made equipment. It is a matter of general knowledge that some metals possess magnetic qualities which are manifest when the metal is placed within a field caused by a direct current of electricity. When thus energized, magnets possess the power to attract smaller masses of certain metals which are free to move, or to attach themselves to constrained metallic objects. Cessation of the electric current decreases, or removes the effectiveness of the magnetic influence. A magnet suspended from a crane is constrained in its movement; hence it is possible for a magnet to pick up free objects of greater weight than the magnet itself.

Magnets are manufactured in a variety of designs including duplex and trefoil, or cloverleaf, types for handling sheet metal coils and other special uses. Rectangular magnets for handling rails and structural steel and iron shapes provide a uniform contact area for each item of the load. These are made in a variety of sizes running from 33 to 80 in. in length.

Circular magnets are more generally used in railroad maintenance work than are other shapes, as they are adaptable to a greater variety of applications.

The assembly of a circular magnet consists of a frame, or cover of soft steel, to which are attached, by bolts, an outer ring which forms one pole of the magnet and a circular central plate which forms the other pole. The electric coil which energizes the poles, is composed of a flat insulated strip conductor contained in a cage, or frame, securely fastened to the cover. The cover is provided with suitable openings through which all vacant spaces within the magnet may be filled with hot asphaltum, or other suitable insulating sealing compound, as a moisture penetration preventive while the magnet is cooling.

Power plants for magnets should be independent engines or motors if possible. The driving of magnet generators from a power take-off is possible but not as satisfactory as from an independent engine. When a crane begins to make a lift, the crane engine is retarded momentarily. This slows the magnet generator when driven from the crane engine and a lower voltage results just when it is desired to get as large a load on the magnet as possible. The power rating of the engine driving the generator should be high enough so that it can be used several years before it fails to develop enough power to give the generator its full rating. A good rule to follow is to provide about 30 percent more engine power than necessary to develop the full output of the generator when the engine is new.



Cross Section of An Electromagnet.

(1) Leads from source of electricity; (2) Inner terminal compartment, covered with rubber gasket; (3) Outer terminal compartment, cover so arranged as to make it water tight; (4) Terminal studs for electrical connection; (5) High temperature impregnating compound; (6) Outer terminal compartment; (7) Inside coil leads (8) Insulating sheets; (9) The magnetizing coil; (10) Insulation for bottom of the coil; (11) Heat-treated through bolts; (12) Flanged outer pole shoe; (13) Suspension chain; (14) Heat-treated through bolts; (15) Suspension lugs; (16) Magnet body; (17) Coil spool; (18) Top plate of coil spool; (19) Sealing disc; (20) Recesses in ribbed coil shield; (21) Coil shield; (22) Tapped holes to be used for eye bolts when removing the coil unit for inspection; (23) Inner pole shoe.

The table gives some information as to sizes and weights of magnets, as well as the loads that can be lifted at each pass.

ELECTROMAGNET CHARACTERISTICS

Magnet Size Outside Drum (In.)	*Magnet Net Weight (Lb)*	*Magnet Load Lift in Heavy Melting Scrap (Lb.)*	*Generator Capacity Req'd. Kw.*	*D. C. Amp. 230-Volt*	*Head-room Required*	*Size of Duplex Flexible Cable*	*Magnet Used For*
18	445	150	½	2.2	22"	No. 14	Very light scrap
24	840	275	2	6.9	28	No. 14	Pipe, light scrap
29	1300	550	2½	8.5	30	No. 14	Small crawler cranes misc. work.
36	2000	800	3	15.0	34	No. 10	Maintenance of way scrap and rails.
39	2100	900	4	18.0	36	No. 8	Scrap & material yards with loco. cranes.
45	3500	1580	10	33.0	42	No. 8	Large cranes.
55	6300	2200	10	40.0	50	No. 8	Large cranes.
65	8800	3500	15	58.0	56	No. 4	Heavy tonnage work.

Reversing switches which give a quick discharge of the load are a very definite requirement for successful magnet operation. Some of these are partly automatic, returning to the off position shortly after they are reversed. Operators should keep the current off a magnet for the return swing and until it has been set down on the load. Then the current switch is turned on, and after several seconds another lift can be made.

Keep all electromagnet bolts tight and see that the electrical connections are well insulated. When not in use, the magnet should be kept dry and set up on blocks so it will not absorb moisture from the ground. The chain links of the magnet should be greased where they wear, as their life can be lengthened appreciably by such care.

The circuit breaker switch box should be carefully kept both dry and clean so that dust and moisture cannot get to the contact surfaces. Too much emphasis cannot be placed on keeping all electrical connections tight so that no arcing will occur, as that would increase the generator load and damage the connections. Proper cable connectors should be used with each magnet installation. Each connector should be single-pole and rated at 100 amp. The magnet leads are clamped over the crane hook for protection. The connectors should be so designed that they can be taken apart quickly without twisting either the power or magnet leads.

It must be remembered that there is a wide variation between the volumetric weights of steel turnings which are very bulky and such concentrated loads as pig iron, which may affect the relative weights the magnet can handle. The 18-in. magnet will lift only about 50 lb. of turnings but will readily lift 150 lb. of pig iron.

Many magnet-equipped cranes employ the drum used for the pull line on drag lines, or the holding line on cranes, to pull the magnet toward the machine so that it will sweep the ground to pick up small scrap. This also enables the operator to let the magnet swing out farther than directly under the boom tip when he is spotted for a scrap bin or scrap car at the proper distance.

Magnets are not skull crackers; they should be placed on the loads carefully and as squarely on any flat surface as possible. The magnet should not strike the load on the side as this tends to loosen the magnet parts.

The use of electromagnets has been encouraged as a means of getting more work done with machines and equipment. It has also resulted in some cases in providing a safer way of handling materials, the manual movement of which has led to finger and hand injuries. Angle bars, tie plates, rail anchors and swich materials are examples of

materials which can be handled satisfactorily with electromagnets. Materials in kegs such as bolts, nuts and spikes have also been moved by electromagnets.

The fact must not be overlooked that the selection of a magnet for a lifting problem should be based upon the material to be handled, which may entail the use of a quadrupolar or duplex type. Magnets are usually wound for 230 volts; however, they can be secured if necessary for 115 or 550-volt current. The electrical power must be direct current; if only alternating current is available, a motor-generator set may be used to supply the direct current.

Use of an electromagnet often requires the employment of but one man, the operator of the machine that has been equipped for magnet work. Machines involving the use of hooks, clamps or any other devices for picking up a load require another man called the "hooker" to attach the rail clamp, sling, chain, or device to make the lift. It is this part of the work that offers possibilities both in economy and safety.

Conclusions

Electromagnets may be used to handle materials in much maintenance of way work. The attainment of economy in doing work along the right-of-way imposes the same problems that are encountered in a material or scrap yard. The operation may involve work train equipment or it may call for crawler or truck mounted machines which move to the work. The use of magnets will no doubt be expanded in the future.

Report on Assignment 10

Oil Filters

C. M. Angel (chairman, subcommittee), G. E. Boyd, R. E. Buss, C. L. Fero, A. J. Flanagan, C. R. Knowles, W. E. Kropp, F. H. McKenney, E. H. Ness, T. M. Pittman, F. H. Rothe, J. C. Ryan, J. N. Todd, Roy Wade.

Your committee presents this final report as information.

The importance of better lubrication and fuel for combustion engines has resulted in expanded research for controlled production methods to produce the best oils possible.

The possibilities for satisfactory and economical use of the oil lie in the maintenance officer in charge of the equipment. That is, to keep the oils in proper condition during their life, continually removing moisture, unburned fuel, road dirt, carbon, metal particles, and sludge—these being the items which damage combustion engines and shorten their life between the repair periods.

The only manner in which oil can be clarified is by proper continuous filtration, therefore, the purpose of this report is to present data that will assist the user in obtaining a better understanding of oil filters, their operation and maintenance.

Types of Filters

Filters are used for removing the impurities, or foreign matter from lubricating oil, gasoline and fuel oil for combustion engines. In operation, a certain percent of the oil pumped is fed to and passed through the filter. In passing through the filter, the lubricant goes through a filtering cartridge, or other material, such as waste, Fuller's earth, etc., which strains out large particles and absorbs fine colloidal materials. However, care should be exercised to select proper filters where the oil used contains additives. After passing through the filter, the oil goes back to the crank case to mix with the other oil for general lubrication of the engine.

Filters for lubricants fall in several classifications, those that use a removable cartridge, or absorbent material which is loosely packed in the filter, and the other type which has the filtering material sealed in the container, making it necessary to replace the entire assembly when the filter is changed. The average maintenance officer is familiar with these types of filter.

It is felt that edge filtration warrants some description. The filter cartridge is constructed of flat disc plates separated by spacer pieces of predetermined thickness placed edgewise to the flow. Solids larger than the space between strips cannot pass. This is known as edge filtration. This type of filter has been known for a considerable period of time; however, its general use was retarded due to extreme difficulty involved in cleaning. This filter now has an arrangement in its construction whereby a handle on top is turned, and the solids which have accumulated on the cartridge are removed as they reach the cleaner blades, and all solids stopped by the filter discs are removed regardless of whether they merely adhere to the edges of the discs or are actually lodged between them.

Lubricating oil filters are manufactured for engines of every size, and in replacing the filters, it is only necessary to make the renewal with the same size as was originally provided on the engine. However, in general, the correct filter size is determined by the engine displacement, but selection should also be governed by the severity of the engine's service. It should be borne in mind that modern oil pumps of combustion engines deliver from 50 to 100 percent more oil than the bearings can take. Therefore, with any reasonable size filter, the pressure is seldom affected and all the oil in the engine travels through the filter many times per hour. A large filter is good for longer service than a small one and reduces the renewal cost.

When changing sizes of filters, or applying filters to engines not so equipped, a filter manufacturer should be consulted to secure expert advice.

Reasons For Oil Filter Use

Lubricating oil filters remove moisture, unburned fuel, road dirt, carbon, metal particles and sludge; therefore, their use results in economical engine operation, due to the following:

1. Less frequent oil change, as it keeps the oil free from contamination.
2. Oil consumption is reduced because the piston-ring grooves remain free of gum, carbon, etc., for a longer time, and therefore do not stick, and oil is not passed into the firing chamber to mix with the fuel and pass out the exhaust.
3. Motor parts are not subjected to abnormal wear caused by dirt, sludge, and abrasives in the lubricating oil.

In general, the use of lubricating oil filters saves replacement and repairs of piston, piston rings, piston pins, piston pin bearings, connecting rod bearings, crankshaft, valves, valve guides, valve seats and gaskets.

Lubricating oil filters can be built in a battery of two or more. Practice in this respect would be governed by the size of engine and other existing circumstances.

Filters For Fuel Oil For Combustion Engines

Gas engines are usually equipped at some location in the fuel line with a closed well in which there is a chamois skin filter, the gasoline passing through the chamois skin before going to the carburetor.

In diesel engines the fuel oil is pumped under pressure to injectors which feed a fine spray into the combustion chamber of the engine. In order to make this spray as fine

as is required, the openings in the injectors are extremely small, so small, in fact, that invisible particles of dirt, or oily gum can cut down, or shut off entirely, the flow through the injectors.

Under some circumstances, certain kinds of contaminating substances appear in fuel oil. To protect the life and performance of the engine, these must be removed; therefore, a fuel oil filter is absolutely necessary on diesel engines. Also, the filter must be extremely efficient. It must remove all the dirt, gum, and other contaminants from the fuel oil, and trap them inside the filter.

In selecting filters for diesel engines, the manufacturer's guarantee as to the efficiency of the filter will have to be accepted until proved faulty in service; however, as to capacity in general, it is a safe rule to allow 150 to 200 cu. in. of filtering capacity for each 100 hp. of diesel engine capacity, and the same amount for each 125 hp. of gasoline engine capacity.

On large engines, it is necessary to use large tandem or double type filters, or mount single units in parallel. The installation should be in duplicate so when one battery of filters is being cleaned, the engine can be operated on the other set. This gives continuous operation of the engine.

Maintenance of Lubricating and Fuel-Oil Filters

It can be observed whether oil is safely clean or dangerously dirty by looking at the oil on the measuring stick or by taking a small sample.

When using filters, a schedule should be set up as to when the filter should be cleaned, as each filter manufacturer furnishes instructions with his filters, and these should be followed to obtain the best results.

The operation of most filters is the same, that is, 5 to 10 percent of the oil pump capacity is fed to the filter through inlet holes, after which it passes through the outlet back to the crank case. When the oil is cloudy or dirty, it is only necessary to check the inlet and outlet pipes to ascertain if they are stopped up. If the pipes are open, it is evident that the filter requires attention. If the filter is of the closed sealed type, an entire new one should be applied; if it is of the removable filter type, a new element should be applied; and if it is of a type that can be cleaned, it should be washed, following the instructions set up by the manufacturer. In all cases, the sludge should be washed from container before applying the replaced filter element.

Fuel oil filters are handled in a similar manner, based upon their type and construction. It is very important that they be maintained to a high point of efficiency so that no foreign matter in the fuel will cause an engine failure due to clogging of nozzles.

Conclusions

1. Lubricating oil filters are necessary in keeping the oil free from foreign substances. They will prolong the service life of engines between shopping periods.

2. Should it be desired to change from one filter to another, the capacity required should be discussed with a filter expert.

3. The change of a filter of the sealed type, the replacement of a removable cartridge, and the removal and cleaning of a washable type filter should be based either on the hours of service or the mileage made, although the need for servicing at other times may be indicated by the appearance of the oil.

4. No fixed maintenance procedure can be set up for cleaning and reconditioning all filters. The manufacturer's instructions should be followed for the particular filter in use.

5. If oil is dirty or cloudy, check the inlet and outlet pipes and if both are open, give the filter the attention recommended by the manufacturer.

Report of Committee 8—Masonry

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H. E. Burr, *Vice-Chairman,*
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H. F. Smith
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H. J. Voelker
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E. P. Wright
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including revision of Specifications for Portland Cement, deletions and revisions of terms and definitions in the Glossary, and certain revisions of other sections; with the recommendation that they be adopted for publication to replace corresponding material now in the Manual..... page 206

2. Specifications and principles of design of plain and reinforced concrete for use in railway bridges, buildings and culverts, collaborating with Committees 1, 5, 6, 7, 13 and 15.

   No report.

3. Progress in the science and art of concrete manufacture.

   No report.

4. Specifications for foundations, including excavation, cofferdam, piling, etc., collaborating with Committee 1, on soil mechanics, and with Committee 7, on bearing power of wood piles and pile driving.

   No report.

5. Methods and practices of lining and relining tunnels, collaborating with Committee 1.

   No report.

6. Bibliography and review of current engineering literature pertaining to railroad masonry work.

   No report.

7. Pressure grouting.

   No report.

AREA Bulletin 457, January 1946.

8. Specifications for concrete and reinforced concrete railroad bridges and other structures.

No report.

9. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

No report.

The Committee on Masonry,
A. N. Laird, *Chairman.*

Report on Assignment 1

Revision of Manual

G. E. Boyd (chairman, subcommittee), A. B. Chapman, M. Hirschthal, J. A. Lahmer, J. F. Leonard, C. P. Marsh, B. J. Minetti, W. M. Ray, J. L. Rippey, C. P. Schantz, G. E. Shaw, F. R. Smith, C. A. Whipple.

The committee submits the following recommendations for adoption and inclusion in the Manual.

1. Delete the following terms and definitions from the Glossary of the Manual:

Abutment
Acid treated finish
Aggregate
Arch masonry
Ashlar
Backing
Batter
Bed
Bed joint
Block rubble
Broken coursed
Cast-in-place piles
Clamp
Coarse aggregate
Column
Column capital
Concrete
Construction joint
Coping
Course
Course bed
Coursed
Crown
Crushed slag
Crushed stone
Crusher-run rock
Culvert
Deformed bar
Diagonal direction
Dimension stone
Dowel
Dressing
Dry masonry
Expansion joint
Faced surfaces
Final set
Fine aggregate
Fine pointed
Finish
Flush (adj.)
Flush (verb)
Form
Gravel
Grout (verb)
Haunch
Header
High early strength cement
Initial set—(of cement)
Joint
Lewis

Lock
Masonry
Monolithic concrete construction
Mortar
Natural bed
Panel length
Parapet
Paving
Pedestal
Pedestal footing
Pier
Premixed aggregate
Premolded concrete piles
Quick setting Portland cement
Ratio of reinforcement
Rectangular direction
Reinforced concrete
—Bond
Retaining wall
Riprap
Rock-faced
Rough pointed
Rubbed
Rubbed finish
Sand
Sand blast finish
Set (noun)
Sieve analysis
Slope wall
Smooth pointed
Spaded finish
Spall (noun)
Stone screenings
Stretcher
Strut
Substructure
Supercement
Tooled finish
Uncoursed
Wall beam
Washed or scrubbed finish

2. Revise the definition of terms in the Glossary of the Manual, as follows:

(Present)

Arch (Ring or Rib).—A curved structural element designed to transmit applied loads to its supports by direct compression, or by direct compression combined with bending and generally producing inclined reactions at its supports.

(Proposed)

Arch (Ring or Rib).—A curved structural element designed to transmit applied loads to rigid supports by direct compression, or by direct compression combined with bending and generally producing inclined reactions at its supports. *8*

(Present)

Consistency.—A general term used to designate the relative plasticity of freshly mixed concrete or mortar.

(Proposed)

Consistency.—A general term relating to the state of fluidity of the mixture, embracing the entire range of fluidity from the driest to the wettest possible mixtures. The consistency of freshly mixed concrete is measured by the standard slump test. *8*

(Present)

Fineness Modulus.—Of aggregates is the sum of the percentages determined in the sieve analysis, divided by 100 (see Sieve Analysis).

(Proposed)

Fineness Modulus.—An index number denoting the fineness or coarseness of an aggregate; its numerical value equals the sum of the percentages by weight coarser than each of the specified standard sieve sizes, divided by 100. *8*

(Present)

FOUNDATION.—The natural material which supports the structure, and its loads, whether strengthened or not by the use of piles or other means to secure adequate bearing.

(Proposed)

FOUNDATION.—Material, including piling or other special construction, which supports the structure and its loads. *S*

(Present)

GROUT (noun).—A fluid mixture of cement and water or of cement, sand and water.

(Proposed)

GROUT (noun).—A fluid mixture of cement and water or of cement, sand and water, with or without admixture. *S*

(Present)

LAGGING.—Strips used to carry and distribute the weight of an arch to the ribs or centering during its construction.

(Proposed)

LAGGING.—Strips of sheeting used to transfer weight or pressure to centering or other supporting members, commonly used in construction of tunnels, arches and shafts. *S*

(Present)

RUBBLE CONCRETE.—Concrete in which rubble stone is embedded. (See Concrete.)

(Proposed)

RUBBLE CONCRETE.—Concrete in which rubble stone is embedded. *S*

(Present)

SCABBLED.—Having irregular surface, the variations of which do not exceed ¾ inch from the pitch line. (See Dressing.)

(Proposed)

SCABBLED.—Having irregular surface, the variations of which do not exceed ¾ in. from the pitch line. *S*

(Present)

SLUMP.—The shortening of the height of a standard test mass of freshly mixed concrete, used as a measure of workability in accordance with the standard method.

(Proposed)

SLUMP.—The shortening of the height of a standard test mass of freshly mixed concrete, used as a measure of consistency in accordance with the standard method. *S*

3. Adopt the following terms and definitions for inclusion in the Glossary of the Manual:

PLASTICITY.—The property of fresh concrete that permits it to be readily molded, but which allows it to change over slowly upon removal of the confining mold. Plastic concrete maintains its homogeneity while flowing sluggishly, neither crumbling through dryness nor segregating through over-fluidity. *S*

WORKABILITY.—There is no standard or universally accepted measure of workability, but as used herein when applied to freshly mixed concrete, it indicates the ease with which it can be handled, transported and placed with the minimum loss of homogeneity. *S*

4. Revise the heading of the "Design Section" on page 8–35 to correspond to that on page 8–1, as follows:

(Present)

SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE, PLAIN AND REINFORCED
III DESIGN

(Proposed)

SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE RAILROAD BRIDGES AND OTHER STRUCTURES
III DESIGN

5. Revise the first paragraph of Section 302–3, Live Load, on page 8–36, as follows:

(Present)

The Standard AREA live load for railway structures supporting track is recommended for main line structures. On branch lines and in other locations where the loading is limited to the use of light equipment, or cars only, the live load may be reduced, as directed by the Engineer. The loads shall be proportional to the standard and shall have the same axle spacing.

(Proposed)

The recommended live load for each track is the Cooper E–72 load for main line structures.* On branch lines and in other locations where the loading is limited to the use of light equipment, or cars only, the live load may be reduced, as directed by the engineer. The loads shall be proportional to those recommended for main line structures and shall have the same axle spacing.

6. Revise the definition of the symbol "f'_c" appearing at the bottom of page 8–37, as follows:

(Present)

where f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6-inch by 12-inch or 8-inch by 16-inch cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field and the Tentative Method of Making Compression Tests of Concrete.

(Proposed)

where f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6-in. by 12-in. or 8-in. by 16-in. cylinders made and tested in accordance with ASTM Specifications C 31 and C 39.

7. Revise the details of Figs. 15 to 18, inclusive, Retaining Walls, appearing on page 8–86 as shown on the next page.

8. Revise paragraph 11, Section 315, Design of Concrete Transmission Poles, appearing on page 8–75, as follows:

(Present)

The reinforcing steel shall conform to the AREA specifications for Intermediate Grade of Reinforcement Bars. The allowable working tensile stress shall not exceed 16,000 pounds per square inch.

* See live load diagrams Fig. 1502 and 1503 of Specifications for Steel Railway Bridges, Chapter 15, Iron and Steel Structures.

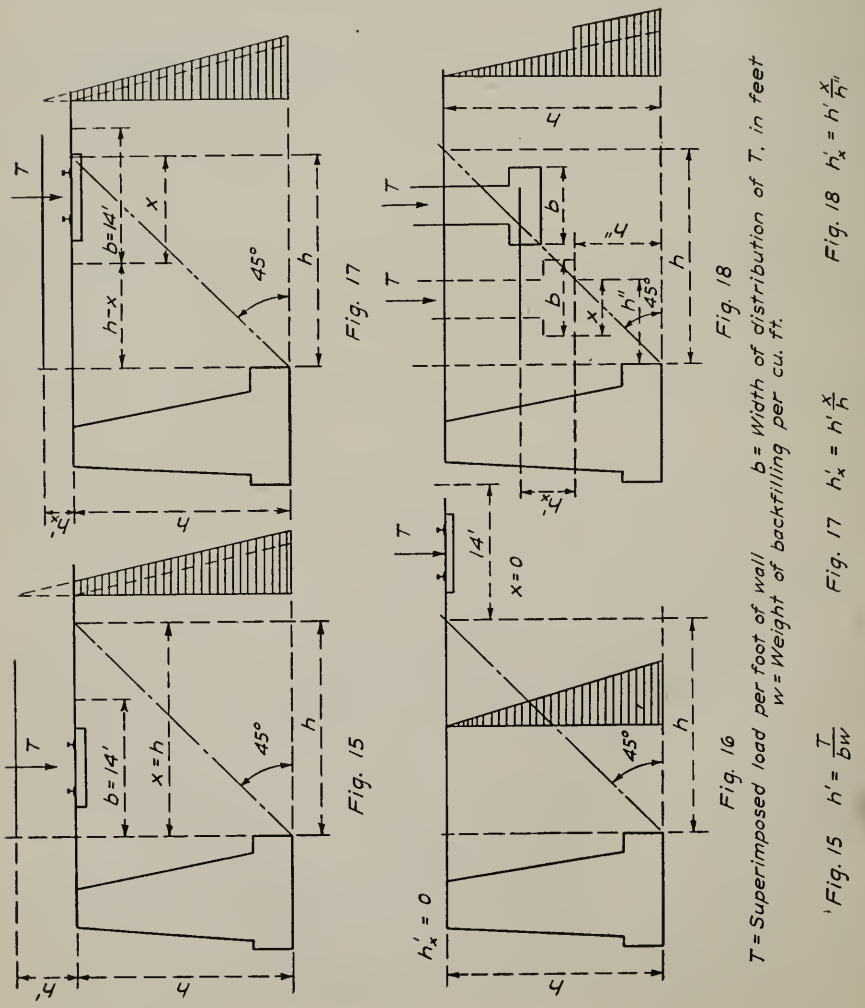
(Proposed)

The reinforcing steel shall conform in quality to the current ASTM Specifications, A 15, Intermediate Grade. The allowable working tensile stress shall not exceed 16,000 lb. per sq. in.

9. Revise subparagraph 1 (b) of Section II Design, of Specifications for Rigid Frame Concrete Bridges, appearing on page 8–73.1, as follows:

(Present)

(b) Live load of the intensity and distribution specified for highway or railway bridges by the American Railway Engineering Association.



(Proposed)

(b) Live load of the intensity and distribution as provided by Specifications for Concrete and Reinforced Concrete Railroad Bridges and Other Structures.

10. Withdraw from the Manual, Emergency Specifications for Portland Cement, ASTM Designation EA-C 150 and Standard Specifications for Portland Cement, ASTM Designation C 150-42, and substitute the following:

Standard Specifications for Portland Cement, ASTM Designation C 150-44.

11. Revise Appendix A, ASTM Specifications and Designations, appearing on page 8–25, as follows:

(Present)

C 109-37-T Method of Test for Compressive Strength of Portland Cement Mortars

(Proposed)

C 109-44 Method of Test for Compressive Strength of Hydraulic-Cement Mortars

(Present)

C 150-42 Portland Cement

(Proposed)

C 150-44 Portland Cement

Insert the following:

C 183-44 Methods of Sampling Hydraulic Cement
C 114-44 Methods of Chemical Analysis of Portland Cement
C 114-44-T Methods of Chemical Analysis of Portland Cement
C 115-42 Method of Test for Fineness of Portland Cement by Means of the Turbidimeter
C 151-43 Method of Test for Autoclave Expansion of Portland Cement
C 191-44 Method of Test for Time of Setting of Hydraulic Cement by the Vicat or Gillmore Needles
C 190-44 Method of Test for Tensile Strength of Hydraulic-Cement Mortars.

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT

1946

The same as ASTM Designation C 150–44

Scope

1. These specifications cover five types of portland cement, as follows:

Type I.—For use in general concrete construction when the special properties specified for types II, III, IV, and V are not required.

Type II.—For use in general concrete construction exposed to moderate sulfate action, or where moderate heat of hydration is required.

Type III.—For use when high early strength is required.

Type IV.—For use when a low heat of hydration is required (Note.)

Type V.—For use when high sulfate resistance is required (Note).

Note.—Attention is called to the fact that cements conforming to the requirements for type IV and type V are not usually carried in stock. In advance of specifying their use, purchasers or their representatives should determine whether these types of cement are, or can be made available.

Basis of Purchase

2. The purchaser should specify the type or types desired. When no type is specified, the requirements of type I shall govern.

Definition

3. For the purpose of these specifications, portland cement is the product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates, to which no additions have been made subsequent to calcination other than water and/or untreated calcium sulfate, except that additions not to exceed 1.0 percent of other materials may be interground with the clinker at the option of the manufacturer, provided such materials in the amounts indicated have been shown to be not harmful by tests carried out or reviewed by Committee C–1 on Cement.*

NOTE.—Tests to determine whether a proposed addition is not harmful will be carried out or reviewed by Committee C–1 on Cement, for those making requests. In the year following that in which an addition has been declared not harmful by the committee, the name of the addition and the amount permitted shall appear as an addendum to Section 3 in a revision of the specifications.

TABLE I.—CHEMICAL REQUIREMENTS

	Type I	*Type II*	*Type III*	*Type IV*[a]	*Type V*[a]
Silicon dioxide (SiO_2), min., per cent	----	21.0	----	----	24.0
Aluminum oxide (Al_2O_3), max., per cent	----	6.0	----	----	4.0
Ferric oxide (Fe_2O_3), max., per cent	----	6.0	----	6.5	4.0
Magnesium oxide (MgO), max., per cent	5.0	5.0	5.0	5.0	4.0
Sulfur trioxide (SO_3), max., per cent	2.0	2.0	2.5	2.0	2.0
Loss on ignition, max., per cent	3.0	3.0	3.0	2.3	3.0
Insoluble residue, max., per cent	0.75	0.75	0.75	0.75	0.75
Ratio of AL_2O_3 to Fe_2O_3	----	0.7 to 2.0	----	----	0.7 to 2.0
Tricalcium silicate ($3CaO.SiO_2$),[b] max., per cent	----	50	----	35	----
Dicalcium silicate ($2CaO.SiO_2$),[b] min., per cent	----	----	----	40	----
Tricalcium aluminate ($3CaO.Al_2O_3$),[b] max., per cent	----	8	15	7	5

[a] See Note, Section 1.

[b] The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

The percentages of tricalcium silicate, dicalcium silicate, and tricalcium aluminate shall be calculated from the chemical analysis as follows:

Tricalcium silicate =
$(4.07 \times \text{per cent CaO}) - (7.60 \times \text{per cent } SiO_2) - (6.72 \times \text{per cent } Al_2O_3) - (1.43 \times \text{per cent } Fe_2O_3) - (2.85 \times \text{per cent } SO_3)$

Dicalcium silicate =
$(2.87 \times \text{per cent } SiO_2) - (0.754 \times \text{per cent } 3CaO.SiO_2)$

Tricalcium aluminate =
$(2.65 \times \text{per cent } Al_2O_3) - (1.69 \times \text{per cent } Fe_2O_3)$

Oxide determinations calculated to the nearest 0.1 per cent shall be used in the calculations. Compound percentages shall be calculated to the nearest 0.1 per cent and reported to the nearest 1 per cent.

* The committee has declared as not harmful the inclusion of the material known commercially as TDA (composed of triethanolamine and highly purified soluble calcium salts of modified lignin sulfonic acids), manufactured by the Dewey and Almy Chemical Co., when added in an amount not exceeding 0.043 percent by weight of the cement, except that in Type III cement a maximum of 0.08 percent by weight may be used.

Chemical Requirements

4. Portland cement of each of the five types shown in Section 1 shall conform to the respective chemical requirements prescribed in Table I.

Physical Requirements

5. Portland cement of each of the five types shown in Section 1 shall conform to the respective physical requirements prescribed in Table II.

TABLE II.—PHYSICAL REQUIREMENTS

	Type I	*Type II*	*Type III*	*Type IV*[a]	*Type V*[a]
Fineness, specific surface, sq. cm. per g.:					
Average value, min.	1600	1700	----	1800	1800
Minimum value, any one sample	1500	1600	----	1700	1700
Soundness:					
Autoclave expansion, max., per cent	0. 50	0. 50	0. 50	0. 50	0. 50
Time of setting (alternate methods):[b]					
Gillmore test:					
Initial set, min., not less than	60	60	60	60	60
Final set, hr., not more than	10	10	10	10	10
Vicat test:					
Initial set, min., not less than	45	45	45	45	45
Final set, hr., not more than	10	10	10	10	10
Compressive strength, psi.:[c] The compressive strength of mortar cubes, composed of 1 part cement and 2.75 parts graded standard sand, by weight, prepared and tested in accordance with Method C 109, shall be equal to or higher than the values specified for the ages indicated below:					
1 day in moist air	----	----	1250	----	----
1 day in moist air, 2 days in water	900	750	2500	----	----
1 day in moist air, 6 days in water	1800	1500	----	800	1000
1 day in moist air, 27 days in water	3000	3000	[c]	2000	2200
Tensile strength, psi.:[c] The tensile strength of mortar briquets composed of 1 part cement and 3 parts standard sand, by weight, prepared and tested in accordance with Methods C 190, shall be equal to or higher than the values specified for the ages indicated below:					
1 day in moist air	----	----	275	----	----
1 day in moist air, 2 days in water	150	125	375	----	----
1 day in moist air, 6 days in water	275	250	----	175	175
1 day in moist air, 27 days in water	350	325	[c]	300	300

[a] See Note, Section 1.

[b] The purchaser should specify the type of setting time test required. In case he does not so specify, the requirement of the Gillmore test only shall govern.

[c] The purchaser should specify the type of strength test required. In case he does not so specify, the requirements of the tensile strength test only shall govern. The strength at any age shall be higher than the strength at the next preceding age. Unless otherwise specified, the compressive and tensile tests for types I and II cement will be made only at 3 and 7 days. If, at the option of the purchaser, a 28-day test is required on type III cement, the strength at 28 days shall be higher than at 3 days.

Packaging and Marking

6. When cement is delivered in packages, the name and brand of the manufacturer and the type under these specifications shall be plainly indicated thereon, except that in the case of type I the type need not be indicated. Similar information shall be provided

in the shipping advices accompanying the shipment of packaged or bulk cement. A bag shall contain 94 lb. net. A barrel shall consist of 376 lb. net. All packages shall be in good condition at the time of inspection.

Storage

7. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weathertight building that will protect the cement from dampness and minimize warehouse set.

Inspection

8. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. The following periods from time of sampling shall be allowed for completion of testing:

1-day test	6 days
3-day test	8 days
7-day test	12 days
28-day test	33 days

Rejection

9. *(a)* The cement may be rejected if it fails to meet any of the requirements of these specifications.

(b) Cement remaining in bulk storage at the mill, prior to shipment, for a period greater than 6 months after completion of the tests may be retested and may be rejected if it fails to conform to any of the requirements of these specifications.

(c) Packages varying more than 5 percent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

Methods of Testing

10. The cement shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the ASTM:

(a) Sampling.—Standard Methods of Sampling Hydraulic Cement (ASTM Designation: C 183).

(b) Chemical Analysis.—Standard Methods of Chemical Analysis of Portland Cement (ASTM Designation: C 114–44) and Tentative Methods of Chemical Analysis of Portland Cement (ASTM Designation: C 114–44T).

(c) Fineness.—Standard Method of Test for Fineness of Portland Cement by the Turbidimeter (ASTM Designation: C 115).

(d) Autoclave Expansion.—Standard Method of Test for Autoclave Expansion of Portland Cement (ASTM Designation: C 151).

(e) Time of Setting.—Standard Methods of Test of Time of Setting of Hydraulic Cement by the Vicat or Gillmore Needles (ASTM Designation: C 191).

(f) Compressive Strength.—Standard Method of Test for Compressive Strength of Hydraulic-Cement Mortars (ASTM Designation: C 109).

(g) Tensile Strength.—Standard Method of Test for Tensile Strength of Hydraulic-Cement Mortars (ASTM Designation: C 190).

Report of Committee 7—Wood Bridges and Trestles

S. F. Grear, *Chairman,*
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A. E. Bechtelheimer
C. N. Billings
S. Blumenthal
R. E. Caudle
A. B. Chapman
H. M. Church
F. H. Cramer
G. S. Crites
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W. H. O'Brien
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W. C. Schakel
A. H. Schmidt
F. E. Schneider
J. R. Showalter
E. R. Shultz
R. L. Stevens
A. A. Visintainer
William Walkden
A. M. Westenhoff
Committee

* Died October 22, 1945.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Simplification of grading rules and classification of timber for railway uses, collaborating with other organizations interested.

   No report.

3. Overhead wood or combination wood and metal highway bridges, collaborating with Committee 15—Iron and Steel Structures; and conferring with proper committee of the American Association of State Highway Officials.

   No report.

4. Specifications for design of wood bridges and trestles.

   No report.

5. Improved design of timber trestles.

   No report.

6. Specifications and design of fastenings for timber trestles, including metal joint connectors.

   Progress report, presented as information..... page 216

7. Proper procedure to be followed in renewing creosoted timber ballasted deck trestles.

   Progress report, presented as information..... page 218

8. Design of creosoted timber pile piers for long spans.

   Progress report, presented as information..... page 222

9. Specifications for inspection of timber trestle railway bridges.

No report.

10. Means of conserving labor and materials, including the adaptation of substitute non-critical materials and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

No report.

THE COMMITTEE ON WOOD BRIDGES AND TRESTLES,
S. F. GREAR, *Chairman.*

Gerald Alfred Haskins

Committee 7 has learned with deep regret of the death on October 22, 1945, of one of its members, Gerald Alfred Haskins, engineer maintenance of way of the Akron, Canton & Youngstown Railroad. Mr. Haskins was born at North Adams, Mass., on September 29, 1891. Prior to entering railroad service, he was employed in engineering work for the city of North Adams. He was with the Boston & Maine Railroad from 1919 to 1937, serving as resident engineer and assistant engineer on various construction projects, and later as assistant track supervisor and as assistant bridge and building supervisor. In 1937, he entered service of the Akron, Canton & Youngstown as division engineer and in 1944 became engineer maintenance of way.

Report on Assignment 6

Specifications and Design of Fastenings for Timber Trestles, Including Metal Joint Connectors

W. O. Nelson (chairman, subcommittee), F. H. Cramer, G. S. Crites, R. P. Hart, G. A. Haskins, B. E. Jacocks, R. P. A. Johnson, W. D. Keeney, W. H. O'Brien.

Your committee presents as information the following tentative specifications with request for comment and criticism thereon before offering them a year hence for inclusion in the Manual to replace Specifications for Metal Details Used in Wood Bridges and Trestles, pages 7–5 and 7–6.

SPECIFICATIONS AND DESIGN OF FASTENINGS FOR TIMBER TRESTLES

MATERIAL

1. Wrought Iron

Wrought iron bars and shapes shall conform to current ASTM specifications A 207.

2. Malleable Iron

Malleable iron castings shall conform to current ASTM specifications A 47, Grade 35018.

3. Cast Iron

Cast iron shall conform to current ASTM specifications A 48, Class No. 30.

4. Rolled Steel

Rolled steel plates, bars and shapes shall conform to current ASTM specifications for steel, A 7.

5. Cast Steel

Cast steel shall conform to current ASTM specifications for carbon steel for miscellaneous industrial uses, A 27, Grade B-1.

TYPES OF FASTENINGS

6. Nails, Spikes and Drift Pins

Nails, spikes and drift pins shall be made of wrought iron or rolled steel, square or round, as called for on the plan. Where special heads are not specified, the manufacturer's standard heads will be acceptable. Nails and spikes used for fastening timbers shall be, preferably, of a type having grooved, barbed or otherwise deformed shanks for greater holding power.

7. Through Bolts

Through bolts shall be made of wrought iron or rolled steel with U. S. standard square or hexagon heads and nuts unless otherwise specified on the plans.

8. Washers

Cast washers shall be made of malleable or gray iron. The outside diameter shall be not less than 3½ times the diameter of the bolt on which it is used and its thickness equal to the diameter of the bolt. The diameter of the hole shall be ⅛ in. larger than the diameter of the bolt.

Plate washers shall be made of wrought iron or rolled steel. The outside diameter shall be not less than 3½ times the diameter of the bolt on which it is used, and they shall not be less than ¼ in. thick. The diameter of the hole shall be ⅛ in. larger than the diameter of the bolt.

9. Packing Spools and Separators

Packing spools and separators shall be made of malleable or cast iron, to a size and shape called for on the plans. The diameter of the hole shall be ⅛ in. larger than the diameter of the bolt.

10. Lag Screws

Lag screws, including steel drive dowels and spikes with spirally grooved shanks shall be made of rolled steel. Heads for lag screws shall be U. S. standard unless otherwise specified.

11. Special Castings

Special castings, including such parts as gib plates, angle blocks, etc., shall be made of cast or malleable iron. They shall be true to pattern, free from wind, without injurious defects and of the size and shape specified on the plan.

12. Cap Stringer Fastenings

These include such types of fastenings as shown on page 7–45, Figure 709 of the Manual. They shall be made of wrought iron or rolled steel of the size and shape specified on the plan.

13. Metal Joint Connectors

Spiked grids, cast shear plates and claw plates shall be made of malleable iron.

Split rings, toothed rings, bull dog types, pressed shear plates and clamping plates shall be made of rolled steel.

They shall be of the size and design specified on the plan.

14. Brace Plates and Washer Plates

Brace plates and washer plates include such types of fastenings as are shown on page 7–39, Figure 703 of the Manual. They shall be made of rolled steel to the size and detail shown on the plan.

Report on Assignment 7

Procedure to Be Followed in Renewing Creosoted Timber Ballasted Deck Trestles

H. T. Livingston (chairman, subcommittee), W. H. Downey, C. S. Johnson, J. R. Kelly, J. R. Showalter.

This is a report of progress presented as information.

Introduction

Plans of ballasted deck pile trestles vary in detail, depending upon the requirements as to loading on the individual railroad, the use of long chords for continuity, and whether or not stringers are lapped over caps, or butt joined. The general installation of this type of structure began on most railroads during the period from 1907 to 1912, when the use of creosoted timber was found to be advisable. Since 1907 increased loading has made necessary revisions, which include a larger number of piles in bents, shortening of panel lengths or an increased depth of stringers, increased dimensions of floor plank and braces, the use of timber connectors, grids, and heavier hardware. In practice, the use of this type of structure on some railroads is limited to heights of less than 28 ft. At many locations, a slight revision of grade line is desirable, and may have been deferred until renewal is undertaken. Usually it is desirable to make a raise in grade of not less than 6 in. to provide for ballast raises adjacent to the bridge. It also happens that many existing structures have more than the design depth of ballast because track forces have raised the track across the bridge in connection with a ballast program.

The new structure should conform with the railroad's current standard plan, including the shaping of the embankment to the proper slope, and the proper height of back wall. Most railroads use preframed timbers, which require that piling and bent locations be accurately determined. The first requirement is that an exact plan and elevation be made of the existing bridge. The proposed structure must then be so located that a minimum number of existing piling and bents will be interferred with. It may be found necessary to drive one or more temporary bents to support the old trestle to insure correct bent spacing, or to avoid short and long panels. When panels of different lengths than the railroad's standard plan provides for, are used, the preframed timber is cut, and its life is shortened. The new grade line must be established, and any required realinement predetermined. To insure proper penetration, test piling should be driven every fifth bent. Such piling should be "outside" piles, and so located that they can serve in the completed structure.

Procedure

The procedure of reconstruction, where a raise in grade of more than 6 in. is to be met, requires that the track should be brought to the new grade before any piles are driven. When the stringers in an existing ballasted deck pile trestle are packed as separate chords under each rail, the work of reconstruction is less complicated than where stringers are lapped over caps. To maintain the highest rate of speed of trains during construction, and to permit the economical use of cranes and mechanized equipment, the plan of procedure should be as follows:

Plan of Procedure

Remove inner guard rails and outside ballast retainers.

Replace track ties with sawed ties of uniform thickness. Such ties may be either second-hand bridge ties, or the track ties that are to be left in the track upon completion. Start at one end of the bridge, removing ballast and floor plank, and placing blocking between ties and stringers to insure that the load on each rail is carried by a sufficient number of stringers. This work must be done between passages of trains, and must not stop between bents.

When existing stringers are lapped, that is, not chorded with butt joints, as in an open deck trestle, they must be replaced with a pre-assembled packed chord, ready for installation, adjacent to the bridge. Such assembly should be for as many panels as it is possible to place in service between the passage of trains. Jack up one-half of the track, remove existing stringers on one side, place proper thickness shims on caps, place pre-assembled chord and anchor it to cap, lower track to bearing on newly placed temporary chord. Repeat the operation on the opposite half of the panels that are being changed. This work is continued until the entire existing structure has been crossed, and has become an open deck pile trestle, with its original base of rail elevation. The new temporary chord must be securely anchored to the caps, and the deck must be drift-pinned to the chord to insure maintenance of line.

On trestles of more than 10 ft. in height, a stringer, laid flat on the ends of the caps, and butt joined and drifted to the caps, should be installed to hold bents in line longitudinally with the track. Such flat stringers will serve also as scaffold.

To meet required small raises in grade, shims will be placed on caps. Where a grade raise of more than 18 in. is necessary, it is better to effect such a raise by leaving the chorded stringers in place on the caps, and then place cribbing on top of the stringers. This can readily be done by placing a stringer flat, between the bottom of the track ties and the top of the chord. The next lift can be made by placing bridge ties between the flat stringer and the top of the chord. The next and succeeding lifts will be made by alternating layers of stringers, placed flat, longitudinally, and bridge ties placed transversely, until the final desired track elevation has been obtained. The crib must be so planned and built as to permit proper placing of piles with a minimum shifting of timber. The location of caps in the new bridge should also be determined, and spaces left for such caps, as far as is practicable. The timbers of the crib must be drift-pinned together sufficiently to insure safety.

Fig. 1 shows a method of cribbing that has been used successfully, and which varies from the described plan in that second-hand stringers, bolted together, were used within the crib to effect openings in the crib at bent and cap locations.

After the track has been brought to the final grade of the new structure, the piling should be driven. Piles should be unloaded adjacent to the end of the bridge opposite the end from which driving will start. When a bridge is located more than two miles from the nearest siding, the traffic is dense, and a self-propelled driver is used, it is

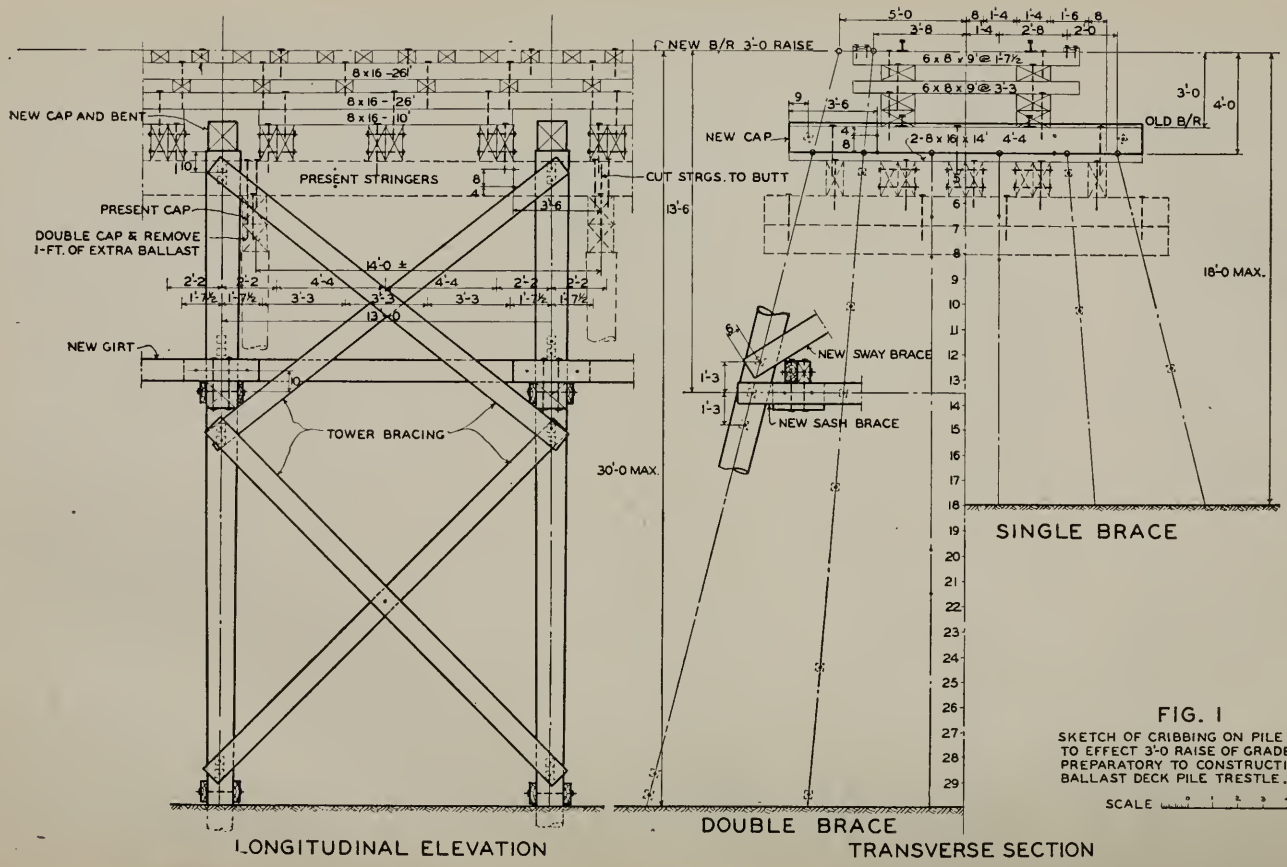


FIG. 1

SKETCH OF CRIBBING ON PILE TRESTLE TO EFFECT 3'-0 RAISE OF GRADE PREPARATORY TO CONSTRUCTION OF BALLAST DECK PILE TRESTLE.

SCALE 0 1 2 3 4 5

desirable to build a spur track to permit prompt clearance of trains. This is especially desirable if the bridge is 10 or more panels long. Piles of the same lengths should be unloaded separately to facilitate heading and sharpening (when done), and insure picking up the proper length of pile. The driver should pick up the pile to be placed in the opposite dump bent, move across the bridge, and drive it accurately to the required penetration. The center pile, or intermediate pile nearest the center of the track should be driven first. The corresponding pile in the next bent should be driven, followed similarly in the succeeding bent, and the work continued across the bridge until one line of corresponding piles in each bent is in place for the full length of the bridge.

This procedure permits the cutting off of piling to clear the track without interfering with the pile driver operations, as well as producing a better bearing value per pile in the completed structure. The only reason for driving each bent complete before starting another is to permit a framing gang to cap and brace immediately. The procedure described will permit a minimum shifting of chords and cribbing as may be required to place piles properly.

When pile driving has been completed, a framing gang should start immediately to complete the structure. The piles must be pulled into true position and held there until they are cut off and the new cap has been placed in position. It is to be understood that the use of a derrick and mechanized tools, the protection of timber by the field application of creosote and close observance of recommended practice, are desirable. The placing of caps will be followed by the application of sway and sash braces to complete the bents. The new backwalls should be installed at this time. After the bents are completed, the new stringers will be placed and floor plank installed, a panel at a time. Track ties will be supported by blocking resting on the new floor plank. A good type of blocking is provided by stringers laid flat on the new floor plank. Track ties must be anchored to the blocking, temporarily, as the work proceeds, to insure maintenance of line.

The stringers should be drifted, or fastened to the new caps, as each panel is completed. Floor plank should be fastened to the stringers as the work proceeds. Where cribbing has been installed for a heavy grade raise, it should be removed from beneath the bridge as the deck installation progresses, and carried back along the track, to reduce fire hazard. After the placing of the floor plank, the outside ballast retainers should be installed. If bridge ties are still in service, they should be replaced with track ties. Ballast should be applied heavily, particularly in the center of the track, after which the blocking for tie supports can be removed, and the track brought to an even bearing on the new deck. The final unloading of ballast will then be made, and track brought to the established line and surface by the track forces.

The bridge forces should now install girts and tower bracing, where they are required. The old sway and sash braces, caps, and girts should be removed. They may be lowered to the ground and piled adjacent to bridge to facilitate loading by a locomotive crane. Old piling will be cut off, preferably one foot below ground level. Piling that may be suitable for further use, such as platform foundations, foundation piling for masonry, or for falsework should be loaded by a locomotive crane. Any timber that is of no further value, and that is to be burned at the bridge site, should be dragged to a point not less than 100 yd. from the new structure. The burning of this old timber should be under careful supervision, and watched until the wood is completely consumed, and no fire hazard exists. During the entire time construction is under way, sufficient fire extinguishers must be on hand and operative. After completion of the work, it is desirable to have a bulldozer level off the ravine and general ground elevation at the bridge site. Any major channel rectification should be made prior to rebuilding the bridge.

Due to cleaning around the piling, through a long period of years, there usually is a ridge on each side of the bridge, which constricts the waterway and lowers the efficiency of the structure.

It must be assumed that the bridge forces will be supervised properly and that they will observe fully the operating rules, timetable rules, and special rules and instructions at all times.

Report on Assignment 8

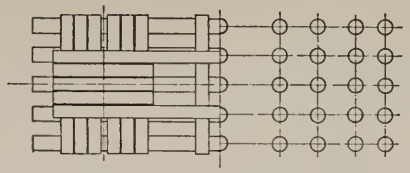
Design of Creosoted Timber Pile Piers for Long Spans

W. D. Keeney (chairman, subcommittee), F. H. Cramer, C. V. Lund, J. M. Montz, W. C. Schakel, F. E. Schneider, J. R. Showalter, A. A. Visintainer.

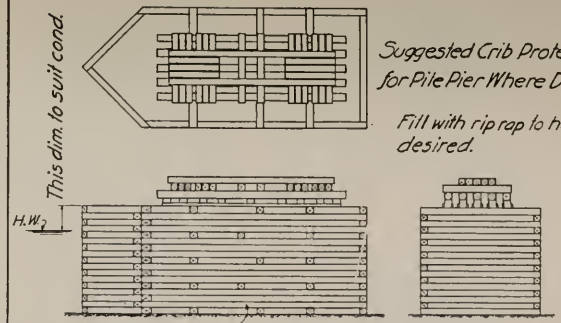
Under this assignment your committee presents as information two preliminary plans of piers for a 150-ft. span with approaches. The drawings were developed after a review of current practice as exemplified by plans of structures in service.

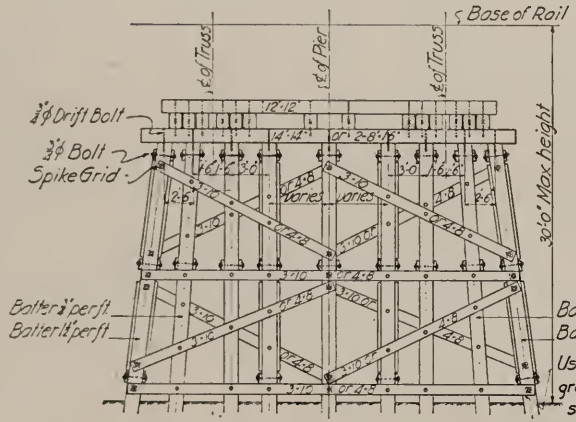
Each plan permits the use of either transverse or longitudinal caps and each method of capping is shown as an alternate. Caps composed of two 8 by 16-in. timbers bolted together are shown also as an alternate to the usual 14 by 14-in. section. After several years of trial installations the former type, though by no means common, has become standard practice on at least one road. It seemed advisable to call this feature to the attention of the Association. Locating the drift bolts in the plane of contact obviates boring through untreated timber and thus exposing the interior of the cap to decay. Moreover, the depth of the section assists materially in distributing loads among the piles of a bent.

Since piers of this type for longer spans consist of a series of conventional bents, the capacity of the several piles is affected by group action. A minimum distance of 3 ft. between piles at the ground line has been maintained, and this spacing has been increased where practicable, as in cases where batter piles are used to prevent unnecessary load concentrations on the subsoil.

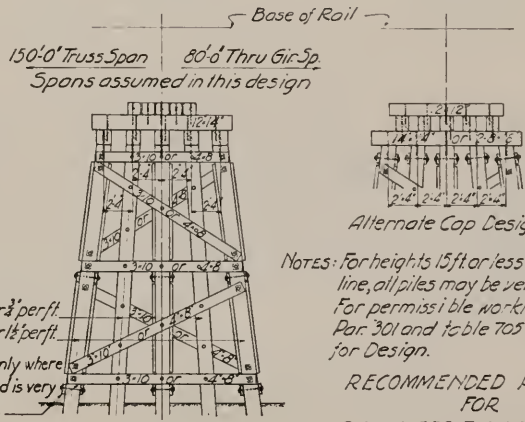


Half Top View Half Pile Plan





Elevation

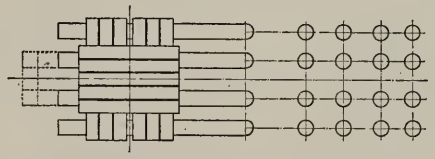


End View.

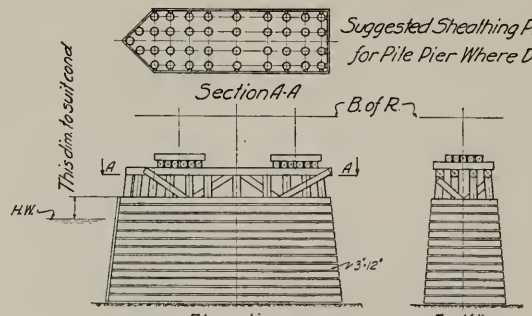
Alternate Cap Design

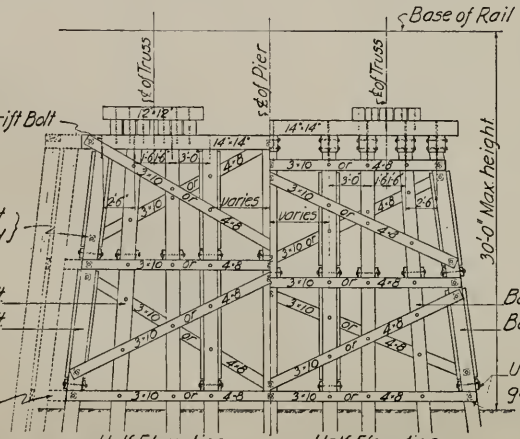
NOTES: For heights 15 ft or less 8 of 2" to ground line, all piles may be vertical. For permissible working stresses see Par. 301 and table 705 in Specifications for Design.

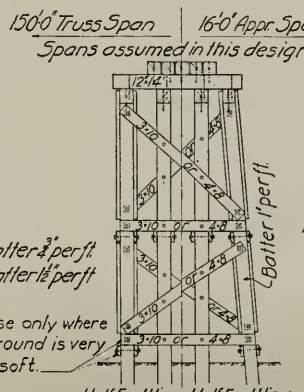
RECOMMENDED PRACTICE
FOR
PILE PIERS FOR LONG SPANS
E-60 LOADING.

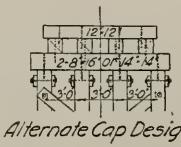


Half Top View Half Pile Plan









Alternate Cap Design

Note: For permissible working stresses see Par 301 and table 705 in Specifications for Design.

RECOMMENDED PRACTICE
FOR
PILE PIERS FOR LONG SPANS
E-60 LOADING

Report of Committee 24—Cooperative Relations With Universities

F. R. Layng, *Chairman,*
Lem Adams
J. B. Akers
J. B. Babcock
W. C. Barrett
T. A. Blair
H. R. Clarke
R. P. Davis
O. W. Eshbach
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E. M. Hastings
W. B. Irwin
R. B. Kittredge
B. R. Kulp
C. T. Morris
W. C. Sadler
F. S. Schwinn
J. M. Symes
Barton Wheelwright
Committee

To the American Railway Engineering Association:

Your committee reports on the following assignments:

Foreword.

A brief statement of the work of the committee..... page 226

1. Stimulate greater appreciation among railway and university officers of

(a) the fundamental importance of instruction in transportation and economics as a qualifying factor for young men desiring to enter railway service with a view to advancement, and

(b) the necessity for presenting courses of instruction based on current railway conditions and taught by men of adequate ability and experience.

Progress report, presented as information..... page 227

2. Direct the attention of universities and colleges to any information and conclusions developed by the Association that may be of special interest or value to them.

Progress report, presented as information..... page 229

3. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure, by cooperating with and contributing to the activities of student organizations in colleges and universities.

No report.

4. The cooperative system of education for railway service.

Progress report, presented as information..... page 234

5. Investigate textbooks and other material available for instruction in railway engineering and make pertinent recommendations thereon.

Progress report, presented as information..... page 238

6. Develop conclusions and recommendations based upon a review of the reports of Committee 24.

Progress report, presented as information..... page 239

The Committee on Cooperative Relations
With Universities,
F. R. Layng, *Chairman.*

AREA Bulletin 457, January 1946.

Foreword

The difficulties under which the railroads have labored during the past four or five years still prevail, but marked progress has been made in preparation for the period of greatly intensified competition that will follow the return to peace-time conditions. As an industry and individually, they are planning to improve their services in every way possible and inasmuch as they have succeeded in strengthening their financial situation, there is every reason to think that they are entering into an era of marked additions to and improvement of their fixed properties, equipment and services. This committee has emphasized the necessity of definite improvement of their personnel if these advancements are to meet with full success. It is the duty of this committee to call to the attention of the railway managements and university authorities alike, the importance of attracting young men of high ability to careers in railway service after they have been trained by our educational institutions. The committee believes that it has fully emphasized the necessity of this in its previous reports, but due to the many adverse conditions that have existed for several years, it is clear that much remains to be done in order to accomplish the objectives which should be reached.

There is a definite shortage of properly trained men available and this is particularly true as to civil engineers. It is believed that the situation is much more critical than is generally realized. If the railroads are to secure their fair share of the men available, there must be a well organized effort on their part to make a place for these men in their organizations at salaries that will be comparable to what they might secure in other industries.

Every effort should be made to increase cooperation between the railroads and the universities. The work of this committee shows clearly the interest of the university representatives in doing everything they can to cooperate. It is not clear that there is a like interest on the part of railway managements, and this committee would be remiss in its duty if it did not point out to the railroads the seriousness of the present situation.

It is recognized that the work of this committee is not a short time task, such as can be completed in a year or even in several years. It is a continuing assignment, having for its objective the creation of a broad realization by railway and college authorities, that our industry requires the most capable leadership available. The industry must prepare to attract to its services, properly trained young men who can look forward to advancement to the highest official positions.

Report on Assignment 1

Stimulate Greater Appreciation Among Railway and University Officers of:

(a) the fundamental importance of instruction in transportation and economics, as a qualifying factor for young men desiring to enter railway service with a view to advancement, and

(b) the necessity for presenting courses of instruction based on current railway conditions and taught by men of adequate ability and experience

E. M. Hastings (chairman, subcommittee), J. B. Babcock, P. O. Ferris, W. B. Irwin, B. R. Kulp, C. T. Morris, J. M. Symes.

This is a brief report of further progress.

The report of this subcommittee presented to the Association in March 1944, Proceedings, Vol. 45, pages 255–260, inclusive, contained views expressed by a number of railway executives in response to the subcommittee's inquiry. The report of the subcommittee presented in March 1945, AREA Proceedings, Vol. 46, pages 131–152, inclusive, contained opinions expressed by the representatives of many of the colleges and universities. Since the publication of these two reports your subcommittee has received additional comment from Rensselaer Polytechnic Institute; an excerpt from this letter, because of the pointedness of the comments therein, is now presented:

> I have read, with interest, the work of your committee and can assure your committee that it can expect full cooperation from our faculty. The training of students for railroad work presents some difficult problems. There are now so many special fields in engineering, particularly civil engineering, and even railroad engineering, that it is not possible to include instruction in but a few special subjects during the undergraduate course. At Rensselaer we had a course in railroad engineering, but changed the title to transportation engineering and included, in addition to railroad problems, instruction in highways, aviation and other forms of transportation.
>
> In addition to the trend of adding technical courses, there has been considerable pressure in recent years, to include more courses in cultural subjects and optional advanced courses. Such subjects as soil mechanics, advanced sanitary engineering and advanced structures have recently been added to our undergraduate curriculum. Despite this trend, I am in favor of devoting more time during undergraduate years to the thorough teaching of basic and fundamental courses, such as mathematics, physics, chemistry and mechanics, so that the student will have a thorough grounding in fundamental engineering and be better able to cope with the advanced applied courses and practice.
>
> It has been my experience that comparatively few boys know, in advance, what branch of engineering they will follow upon graduation, and to specialize in one or two narrow fields will probably work to the detriment of the student in after years. I find that a great many students are swayed by the current popularity of certain branches of engineering as indicated by the fact that during the last prewar year, some 300 freshman students, out of a class of approximately 600, selected aeronautical engineering.

I have had some professional dealings with several large railroads and agree that there is room for improvement in their methods of employment and training men for key positions. Several years ago I spoke to the chief engineer of a large railroad and suggested that he consider for employment a man with an excellent background in railroad engineering who was then available. He was not given consideration because he was approximately 45 years old, and therefore disqualified because of certain group insurance conditions. A short time later I recommended a very promising graduating student, a boy keenly interested in railroad engineering. This time I was told that the policy of the railroad was not to employ men who did not have previous practical experience.

It is my opinion that the graduate engineer should be trained by the railroad companies and he should supplement this training with graduate study, possibly at night. The undergraduate course is now so crowded and the field of engineering so broad, that it is not possible to devote the time to produce specialists.

At Rensselaer we do now, and we will continue to teach many courses directly connected with railroad engineering and I am sure that many graduates would prove their worth to railroad organizations if given the proper opportunities. Many of our graduates now hold important places in this field.

A direct and intimate contact between the railroad companies and the colleges will, I am sure, accomplish all that both might desire.

The publication in *Railway Age* of portions of the report of 1945, above referred to, brought forth some comment which was also carried on in the *Railway Age*. Your subcommittee at this time does not attempt to analyze or discuss the questions brought up by the correspondent but feels, however, that many very challenging questions were raised in the published correspondence and that one of the points brought out therein, namely, that a long range plan is needed in this matter of cooperation between the railways and the universities, is a very sound and pertinent point to be raised and it is now time for some conclusions and recommendations to be drawn from the information which has been developed by the committee. A written comment received by the chairman of the subcommittee from a young man is indicative of the thinking of young men toward railway employment as they come out of colleges and universities. One portion of a paragraph of his letter is here quoted:

Ever since I graduated from Stevens Institute in 1936 I have wondered about the apparent apathy of the railroads towards technically-trained, new employees. There are some exceptions, I know, but even these seem not particularly anxious about going after anyone; rather they expect one to come after them. Feeling as I do, I have followed with interest the several articles in *Railway Age* concerning the future of college men in the railroad business.

The substance of the letter which follows the above quotation indicates very clearly that some railroad lost the chance of getting a very excellent and interested young graduate.

Your subcommittee again calls to the attention of the Association the need for such cooperation with colleges and universities as would tend toward a coordination of their interests, the one in turning out well prepared young men, the other, the seeking of these young men while they are in preparation in order to build them into the railway structure.

Report on Assignment 2

Direct the Attention of Universities and College to Any Information and Conclusions Developed by the Association

That May Be of Special Interest or Value to Them

W. D. Faucette (chairman, subcommittee), R. P. Davis, P. O. Ferris, W. B. Irwin, R. B. Kittredge, Barton Wheelwright.

This subcommittee in 1944 reported comprehensively on a questionnaire that had been sent to the various colleges and universities, making inquiry as to the extent to which they used the AREA Manual and other publications of the Association in their class room instructions, as shown in the Proceedings, Vol. 46, 1945. The complete report of Committee 24 was then sent to all the institutions who had received the original questionnaire. Several replies were received and a follow up was sent to those who had not responded. Representative answers from these have been selected and omission of answers is no indication of lack of interest.

From the replies selected, the following quotations are made:

Nova Scotia Technical College, Halifax, N. S. (F. H. Sexton, President)

The information contained in the report from the official statements of leading universities is of great value.

In Canada we have two great transcontinental railway systems, both of which regularly engage a certain number of engineering graduates each year and provide opportunities for them to secure practical experience and to gravitate to that section of activity in the organization where they are best fitted to function. These railway systems have given me the impression of a greater recognition of the importance of technically trained staff since the outbreak of the war. I am looking forward to a much closer cooperation between our engineering colleges and the railway systems in the future to the mutual advantage of both.

State University of Iowa, Iowa City, Iowa. (F. M. Dawson, dean, College of Engineering.)

I have followed with interest the revived program which the American Railway Engineering Association has had during the last few years. There has been so much written and said that I believe there is now substantial agreement on what should be done. We at the University of Iowa are, therefore, offering our services to cooperate with the railroads, particularly those in this immediate vicinity. I am making one concrete suggestion, which I believe should be put into effect just as soon as possible. In my opinion, the railroads should employ during the summer work period as many students from the colleges of engineering as they can. Our term closes approximately the first of June and opens again about September 20. This leaves 3½ months in the summer for work experience. It so happens that this period coincides with the time when the railroads need extra help. Why not combine the objects of giving work experience to students with the railroads' desire to carry on repair work and new construction during the summer months, and achieve a third object of introducing young men to the desirability of working at railroading as a life occupation?

I am not thinking of limiting the proposed work to new construction. I think it highly desirable that young men should be taken into the railway shops and on other maintenance work. The main thing is to make sure that they are given an opportunity to learn. I doubt also that there should be any commitment regarding future employment. Simply employ them for one summer at a time. The best would stick. I believe we could send at least a dozen young men on work of this character each year, but, of course, this could not be done until the Selective Service System leaves students in the colleges for training.

There are many other ways in which the universities would like to cooperate with the railroads, but I believe this summer training should be started without delay.

Rensselaer Polytechnic Institute, Troy, N. Y. (H. O. Sharp, acting head, Department of Civil Engineering.)

I was very much interested in the report of Committee 24 and the comments made by some of the schools in reply to your questionnaire. I feel that railroad engineering could be made an important part of our educational program. One thing which is lacking at the present time is a good up to date textbook, and I feel that your committee might very well promote the writing of such a book. It is unquestionably a big job and very likely it will be difficult to find one man who would be willing to attempt such an undertaking. I feel that it is a task for a group of men who are willing to pool their knowledge with possibly one or two men to coordinate all of the information. I find that railroad engineering is an interesting subject and I am sure that it can be made interesting and beneficial to students with the proper approach. The second item which will interest students in railroad engineering is the compensation pay and the opportunities for advancement. This point was brought out in several of the letters submitted to your committee so I am sure that you are aware of this fact.

Harvard University, Boston, Mass. (William J. Cunningham, professor of transportation.)

On receipt of your letter of July 20 I read it and the report of the committee, especially that part covered by your subcommittee, and had no comments to make or additions to suggest. I thought that you had very well summarized the results of your questionnaire.

C. C. Williams, consultant in engineering and industrial education, 129 North Prospect Ave., Madison 5, Wis.

My failure to comment on the committee report does not signify a lack of appreciation of the excellent survey of the situation made by your committee. This assembly of opinions relative to the questions raised is valuable even though they do not afford a solution to the problem. The current practice in not seeking engineering graduates indicates that the railroads find the assistants they desire elsewhere and that technical graduates are not sufficiently interested in a railway career to seek employment under existing conditions. Moreover, the replies do not disclose any disposition on the part of either the railroads or the colleges to modify their procedures to bring them to common ground. Such seems to be the general purport.

High school and junior college graduates can learn the rather empirical procedures of railway engineering almost as readily as an engineering graduate and

can be had at the lower wage scales. The duties of advanced positions demand certain personal qualities even more than technical knowledge and these are likely to be found in noncollege men. On the other hand, the college graduate is not attracted to railroad service because of low starting salaries and the lack of channels of promotion to top positions. Moreover, the youth who learns the apprenticeship way is more likely to continue for life in the railroad service, because the graduate has had glimpses of many fields of opportunity. The latter is not content to continue for months or years on routines which he masters in a week. Railroads obtain their genuine engineering service from the equipment manufacturers on whom they are dependent at present for progress; they employ directly for the routines of operation.

Since most boys with high IQ now go to college, the railroads are not getting their proper share of superior personnel. Higher initial salaries would help. From considerable experience and observation, the additional salary needed to obtain superior ability in a young employee is money wisely spent. On the other hand, the number of such recruited each year should not be disproportionate to the promotion opportunities lest the attractiveness of the service suffer in reputation.

Agricultural and Mechanical College of Texas, College Station, Texas. (A. A. Jakkula, acting vice-director, Texas Engineering Experiment Station.)

I read the report with a great deal of interest and referred it to others who I knew were also interested.

Quite recently I have referred some of our graduates who are returning from the service to the railroad offices in Dallas and Houston. I have not heard from them as to their success in getting employment. I feel certain that if the railroads provide work for our graduates, then the college will adjust its curriculum to provide for their needs.

Illinois Institute of Technology, Chicago 16, Ill. (Henry T. Heald, President.)

It seems to me that there are many ways for increased cooperation between the nation's railroads and the universities. Certainly in the era of keen competition ahead, the railroads will need to obtain their full share of engineering graduates if they are to continue to be successful. Railroad transportation can be and should be an attractive field for young engineers. To accomplish this will require a thorough change in attitude from top to bottom in many of the roads. I received some of my early experience as an employee of one of the large railroads, but if the same attitudes exist now which I found 20 years ago, there is little hope that railroad employment will prove attractive to outstanding men irrespective of what courses are given in the colleges. Fortunately, I think this attitude is changing.

I believe the work of your committee is constructive, and its continued efforts should prove exceedingly useful. I wish you every success.

Purdue University, Lafayette, Ind. (G. P. Springer, School of Civil Engineering.)

There must be a recognition by the railroads of the fact that the college graduate is going out into a competitive field where manufacturing corporations; large contractors, and the various municipal bodies are asking for his services, and unless there is an increase in the salaries offered at starting, and reasonable expectation of promotion in position in not too distant a period in the future, the railroads are not going to get these civil engineering graduates. . . .

The railroads must make the positions and the salaries that they offer, acceptable to these men.

University of Minnesota, Minneapolis, Minn. (S. C. Lind, dean.)

At the University of Minnesota we offer nine courses in railway engineering, two of them for undergraduates including surveying and construction, five courses open to graduates and undergraduates, and two open to graduate students only. A fair proportion of our graduates of civil engineering have always gone into railway work but with the cessation of building railway lines, naturally, this proportion is somewhat smaller than formerly. I am not aware that there is any disinclination toward railway employment among our graduates such as I find expressed in many of the other reports, but I think it possible that some of the newer methods of transportation, particularly by air, are attracting a large number of engineering students who might otherwise be interested in railway engineering. I have the impression that some of the developments in the last war in the field of radar and electronics will directly apply to railway operation and that they should be applied as rapidly as conditions will permit following the war.

I am also convinced that some of the problems of human engineering should be more carefully considered by the railways. They are in sharp competition now with airplane, auto bus and private car transportation. Just at present, of course, the railways have all the traffic they can handle and more, but when troop movements are over and the general public has spent all of its war profits, I think you can expect a return to a competitive basis for business and I believe that there should be more attention paid to the wishes and convenience of the traveling public.

University of Washington, Seattle 5, Wash. (E. A. Loew, dean.)

The subject of this report is indeed of very great interest to us, for it deals with the important question of the relations of the engineering colleges to the railroads. When your bulletin arrived, it was forwarded immediately to the civil engineering department. This department has charge of all courses in railways and transportation. We find that Professor R. G. Hennes, into whose hands the bulletin was put, has written you his comments and also has applied for membership in the American Railway Engineering Association. He informs me also that modifications in the transportation courses offered by our college are at present under consideration as a direct result of the report of your committee.

In closing, may I express my own great appreciation of the excellent work of your committee. It is precisely through friendly and open discussions of our common problems (in a friendly and cooperative spirit) that solutions beneficial to both the colleges and the railroads are secured. Your committee is to be congratulated upon the report that it submitted on the seven assigned topics. They have already proved helpful to us.

University of Illinois, Urbana, Ill. (William A. Oliver, associate professor of civil engineering.)

I shall take advantage of your request for comments to express one or two ideas on this subject of the employment by the railroads of young engineers.

I was told by one railroad engineer recently that his company proposes to establish a systematic method of summer employment for engineering students whereby (a) the railroad could train for future permanent employment, (b) the

student could gain experience and earn money and, (c) he would be given college credit for the work done. The general idea is excellent although, of course, it is not new. However, I can see two objections to item (c). There would be difficulty in assessing the value of such work in terms of college credit and what is even more important, credit courses would be added to an already overcrowded program. In my opinion such summer work could and should be required by the university without college credit.

I have another subject I would like to advance for discussion. One of my students recently came back to school after a vacation experience in the division office of a railroad. I asked him how he liked it. His reply was that he had had a nice experience but that he didn't want to go back because there was no future in railroading. He stated that his chief, the division engineer, only received so much per month and that he couldn't see any chance for himself of even advancing to that position until after many years. I may not be expressing his words exactly but his ideas are there.

Of course this criticism is tied in with the practice of seniority advancement in railroad work. However, as I see it there is something else involved. There is only one chief engineer on a railroad but there is, also, only one chief engineer in a highway department or one chief engineer with the great manufacturing industries such as Westinghouse. In other words, the top ranking positions are limited in number in all industries and always will be. Why is it then that the young man feels that there is opportunity to satisfy his ambition to the extent of his ability with the other industries but not with the railroads? Do the railroads discourage initiative? Are they hidebound with precedent? Do they make him feel that new ideas are not welcome? If they are false, wouldn't it be possible for the railroads to do something to dispel these ideas that prevail in the minds of those of us who are on the outside looking in

Please understand that I raise the above questions only because I believe that there should be promising careers for the young man in the field of railway engineering and I, also, believe that it is to the advantage of the railroad industry to encourage him in that idea.

The preceding comments are very informative, and should be read by the entire membership of the Association, as well as those in the railroad world who are interested in this cooperative relationship. These comments have a special significance especially at this critical time when the need of public relations is so necessary.

Aside from the fact that they are replies to a direct communication, they evidence an interest in cooperative relationship between the railroad industry and the universities and colleges. The time and thought given to these replies are values by this committee.

Report on Assignment 4

The Cooperative System of Education for Railway Service

Lem Adams (chairman, subcommittee), J. B. Akers, J. B. Babcock, H. R. Clarke, O. W. Eshbach, W. B. Irwin, J. M. Symes.

Last year your committee made a brief report on this subject, merely citing, numerically, the purport of replies received up to that time. The committee believes that the membership will be interested in the opinion and/or, practices expressed in some of the replies, which are divided as follows:

1. Railroads that favor the plan and now use it.
2. Railroads that favor the plan but have not used it.
3. Railroads that have used the plan and discontinued it.
4. Railroads that are opposed to the plan, but favor some other.

Neither the name of the railroad, nor of the officer reporting has been shown.

1. Railroads That Favor the Plan and Now Use It

A. *Chief of Personnel.*—Following receipt of your letter of September 15, relating to the employment of college trained men for railroad work, I took the matter up with some of our officers for the purpose of obtaining their opinions.

We have used some of the cooperative students from the University of Cincinnati and they have proved very satisfactory. These boys have worked in positions which generally are not covered by agreements with the labor organizations.

I think I can say that our reaction toward employment of men from the institutions you mention is very favorable and we will be glad to consider applications from them at any time.

B. *Engineering Officer.*—Until the war started we had employed from two to four cooperative students and worked these men in our signal construction forces. I do not believe the system has materially changed since I finished in 1933, and at that time one student worked for a period of three months with some company while the other was attending school during this same period. At the end of this period the student at work returned to school and the one at school took his place at work. In order to accomplish this type of system, it is necessary for the school to teach the course twice. It was the usual practice for the director of the cooperative course to obtain jobs for the students from various concerns in the vicinity.

The training received from one of these courses, in my opinion, is very valuable as it enables a college student to become acquainted with the requirements of industry at the same time he is learning the technical fundamentals. It also gives him an opportunity to study those fundamentals in relation to practical problems while on the job.

We obtained the services of several of these students after they were graduated, however, most of them are now in the Army. We have been unable to obtain the services of such students for the past two years.

C. *Chief Engineer.*—We have for some time been cooperating with the Northwestern University at Evanston, Ill., and also with an institution in Milwaukee, Wis., and we have found such cooperation very satisfactory.

Right now, however, most of the young fellows are in military service. When the war is over and men are again available, we have in mind cooperating as we have done heretofore.

D. *Chief of Personnel.*—Under our collective bargaining agreements with our employees in the various crafts or classes, which include practically all positions of mechanics, helpers, and apprentices, it would not be practicable to permit university students to alternate between school and such positions.

In some branches of our service employing technically trained men, for instance, positions in our engineering department which are not covered by such agreements, it was the practice for several years before World War II to employ men who were taking the cooperative course in engineering. This was disrupted by the war but will be resumed under normal conditions in the postwar period. The colleges with which we have cooperated in this matter are Drexel Institute, University of Cincinnati, Northwestern University Technological Institute, Northeastern University—Boston, Newark College of Engineering, and University of Louisville.

In our traffic and accounting departments, it has not been considered desirable to employ students enrolled in cooperative courses which contemplate dividing their time between college and industry. In these departments it is the view that students should obtain practical experience by taking summer employment in the industry in which they intend to seek employment after graduation.

2. Railroads That Favor the Plan But Have Not Used It

A. *Vice-President.*—I think you are familiar with my ideas on the subject which have been expressed verbally a number of times and as outlined in the address which I made before the S.P.E.E. in Cincinnati on June 24, 1944, portions of which were abstracted in the *Railway Age,* issue of August 19, 1944.

We are very much interested and would be glad to cooperate by employing a few men in the engineering or maintenance of way department for trial purposes.

B. *Vice-President.*—I believe it would be a mistake for educational institutions to drop subjects of railroad engineering from their curriculums, for at no time has the field been more promising for technical graduates in the railroads of this country than presents itself at this time.

We would be glad to consider students for cooperative work and study at the time such students are available and if satisfactory arrangements can be made for such a procedure.

C. *Personnel Director.*—I am quite familiar with this plan, and it is our purpose, as soon as the war is over, to avail ourselves to the extent possible under labor agreements of the plans which the various universities have to offer.

D. *Chief Engineer.*—At the present time we have no connections with any universities that have cooperative courses, but I feel sure that our management will be receptive to the recommendation that we do initiate such practice. It is my hope that we will be able to absorb at least two men each year in our engineering department, and I feel that there should be places for one or two in our mechanical department, and at least one in our operating department.

Until such time as our management has approved the initiation of such plan on our road, all I can say positively to you is that I will do everything I can to bring about the adoption of such plan in the near future.

E. *Assistant to Vice-President.*—This company had a student officer training plan in operation for several years before the war, the men being selected from outstanding graduates of various universities, and we will be interested in what can be worked out along the cooperative plan you suggest, wherein one cooperative student would be employed on the railroad while the student paired with him would continue in his university work.

Shall be interested to know of any specific cases where labor organizations have agreed to the plan proposed, as the percentage limitation of apprentices has generally applied to the shop crafts, and it would be expected that the cooperative plan would be given a much wider application than to employment in the shop crafts alone.

Believe one essential feature required for successful operation of the cooperative plan would be sufficient flexibility to permit the student to be transferred from one department to another and from one division to another, which would affect employment under the jurisdiction of two or more labor organizations.

3. Railroad That Has Used the Plan But Discontinued It

A. *Vice-President.*—We have tried the cooperative system rather extensively in the past. We have come to the conclusion that our student apprentice system is better suited to our needs. Very few of the cooperative students remained with our railroad after completing their course, while the student apprentices selected from civil and mechanical engineering graduates from southern colleges have stayed with us and made railroading their life's work. A large number of general and division officers in operation, engineering and maintenance have come up through this student apprentice course. For the above reasons we would not be interested in again undertaking the cooperative system.

4. Railroads That Are Opposed to the Plan, But Favor Some Other

A. *Vice-President Operations.*—It is highly desirable that interest be stimulated on the part of higher educational institutions to develop courses in railroad engineering, and that railroads undertake a definite program of interesting college men in training for railroading as a life work.

Offhand, I am not particularly impressed with the plan of dividing time between railroad work and school work. My experience leads me to believe that very few boys leaving high school and preparing to take up college studies have any serious idea of what they want to do or in what direction their aptitudes actually may lie. I would like to see a plan undertaken with high school graduates going to work for at least a year on the railroad before taking up college work, or possibly it might be better for them to put in a year of actual railroad work after having completed freshman year at college. Then I think the school work should be continuous until graduation with actual railroad employment only during the summer vacation period.

It is not my idea that graduates completing a college course in railroad engineering necessarily ought to take up railroad employment in the roadway construction or maintenance department or the mechanical or motive power department, simply because they may have completed a civil engineering or mechanical engineering course. The need for college trained men and the opportunities for advancement in the railroad industry apply to other departments. The advantage of college training probably would give opportunity relatively for the most rapid advancement (energy, ambition, and other things being equal) in the field of

station work, telegraph operator, car handling, dispatching, chief dispatching, junior division officers, such as yardmaster, trainmaster, and leading thence to the position of assistant superintendent, superintendent, etc. Likewise, college trained men might expect good opportunities for promotion by taking employment initially as a switchman, brakeman, or fireman. There are good opportunities for college men in the traffic department with initial employment preferably in secretarial or clerical positions.

B. *Vice-President, Engineering.*—For about ten years prior to the depression we had an arrangement with the University of Cincinnati whereby we held open two positions for them to fill. At intervals of four weeks the boys employed were alternated as chainmen or rodmen on our division engineering parties, or in our general office drafting room. Those who came to us were good boys, but one of the drawbacks was the necessity for changing them every four weeks. During that period we had a large engineering force, but when the depression came along it was necessary to make drastic cuts and the above arrangement was discontinued. We have also made it a practice to take on a number of engineering students during summer vacation periods.

It seems to this writer that for sometime after the close of the war there will be a surplusage of seasoned graduate engineers from the armed forces, and various war plants, many of whom will have a preferential status, and that these men will be better qualified for the available jobs than undergraduate students.

My present thought is that so far as civil engineers are concerned, we would not be interested at this time in entering into a cooperative plan such as outlined in your letter. It is our intention so far as possible to confine ourselves to the employment of graduates of engineering schools for work in our engineering department.

C. *Vice-President, Operations.*—This railroad for a considerable period of time in prewar years had a practice of taking each year a number of likely graduates of technical schools and giving them a special apprenticeship training to supplement their technical training and fit them for advancement as supervisors. Our experience with some of the men so developed has been fortunate and I think we would prefer to continue that plan when things are normal again.

D. *Chief Operating Officer.*—Some 20 odd years ago our company adopted the policy of developing officer personnel within the ranks of its employees. To this end, we established a practice that no men could be employed for work on an engineer corps without an engineering degree from a recognized school of engineering. He did not necessarily have to be a civil engineer. In this way, we have developed and are developing men for official positions, superintendents, division engineers, etc. We are well satisfied with the results obtained.

About the same time, with a view of developing officer personnel in our mechanical department, we adopted the policy of employing as special apprentices in the mechanical department men with degrees in mechanical or electrical engineering after being interviewed by officers assigned to that work, giving preference to the sons or close relatives of employees and trained in schools on or not too far distant from our line. Our principal source of supply has been from the University of Missouri, Missouri School of Mines, Purdue University, Texas A&M and the University of Texas. These men, as special apprentices, are assigned to stated periods of work for the acquisition of experience as machinists, blacksmiths, boilermakers, sheet metal workers, electricians, freight and passenger carmen and in the drawing room and stores department. For some time after putting this plan

in effect, the results were not wholly reassuring. Inquiry developed the fact that sufficient care was not taken by the employing officers in determining the qualifications of the applicant in resourcefulness, initiative, perseverance, leadership and a recognition of the need for team work. This was corrected and thereafter the results have been so satisfactory that I doubt whether we would be interested in participating in the plan referred to in your letter.

Qualification for promotion is or should be a continually developing process. From the employer's standpoint, it is highly desirable, in the interest of efficient development of the employee, that he be able to practice tomorrow what he has learned today. It is rather discouraging to the men immediately in charge of the work, after breaking a man in for six months, to lose him and then take another recruit and teach him the same things for another six months. I feel that from the employer's standpoint, it is better to have the man complete his scholastic training before putting him to work in which he will complete his education. Eight years is a pretty long time for a man to earn his degree. After the age of 22 or 23, he will want to get married and start the business of working his way up in the world. We have a man who graduated from the University of Cincinnati, but he completed his work before entering our service, and I might add that he is forging ahead and rendering an excellent account of himself. I feel that men with engineering training entering railway service should be developed by or before the time they are 30 years of age for official responsibilities.

Report on Assignment 5

Investigate Textbooks and Other Material Available for Instruction in Railway Engineering, and Make Pertinent Recommendations Thereon

O. W. Eshbach (chairman, subcommittee), Lem Adams, W. C. Barrett, T. A. Blair, W. B. Irwin, R. B. Kittredge, B. R. Kulp.

This subcommittee reports progress.

A bibliography has been prepared and the following tentative conclusions have been reached:

1. There is no up-to-date or satisfactory textbook on railway engineering suitable for course instruction in American engineering schools.

2. There is some excellent supplementary material which may be used for reference purposes, part of which is in need of being brought up to date.

3. The tendency in the postwar revision of curricula in engineering schools is toward the elimination of special instruction and the incorporation of applications in courses fundamental to many applied fields. There is also an attempt to free more time for social humanistic studies, naturally including economics.

4. There is a desire on the part of some engineering teachers particularly interested in the field of railways to have modern text materials. It is believed that if suitable material could be prepared its use would extend beyond those currently interested.

5. The committee should attempt to outline the content of a modern text on railway engineering and submit it to a reputable publisher or publishers with recommendations, if possible, of men competent to prepare the material for publication.

Report on Assignment 6

Develop Conclusions and Recommendations Based Upon a Review of the Reports of Committee 24

F. S. Schwinn (chairman, subcommittee), J. B. Akers, J. B. Babcock, H. R. Clarke, R. P. Davis, E. M. Hastings.

Your committee has reviewed all of the reports, whether of a progress or final nature, that have been presented under the general title of Cooperative Relations With Universities. These reports appear in Proceedings, Vols. 42 to 46, both included. The resulting conclusions are offered as information.

Conclusions have been developed under each of the assignments previously given to this committee and are stated separately for each of those assignments. These conclusions are drawn from the factual matter collected in the studies as represented primarily by the quoted expressions of railway executives and other railway operating, personnel and engineering officers, of university and college presidents, deans and engineering educators, and of the officers of representative companies covering a broad cross section of the industrial field.

With the opening of the postwar period there will be greatly accentuated competition in every industrial field including that of transportation. Failure to meet this competition will spell disaster. The carefully planned and effectuated employment and assimilation of well trained young men is one of the several means available to the railways in meeting their future competition and it will be desirable to take advantage of every such means.

Conclusions

Respecting—stimulating greater appreciation among railway and university officers of (a) the fundamental importance of instruction in transportation and economics as a qualifying factor for young men desiring to enter railway service with a view to advancement, and (b) the necessity for presenting courses of instruction based on current railway conditions and taught by men of adequate ability and experience:

(a) Some railways have evidenced an appreciation of the fundamental importance of instruction in transportation and economics.

(b) University officers are not inclined to present courses of instruction in railway transportation unless the railways evidence a greater interest in the placement of college trained men in the several fields of railway transportation.

(c) Railway officers will find it desirable to take advantage of the willingness of university officers to supply the railways' requirements in men having the needed basic or fundamental training in transportation subjects.

(d) Other competitive branches of the transportation industry are more active than the railways in taking advantage of the possibilities attached to the employment of men who have received adequate college training in transportation and economics.

(e) Cooperative instruction can be made effective under a joint arrangement between a university and a railroad whereby the railroad offers summer employment. This employment should continue through the summer vacations and should constitute a carefully developed and properly supervised course of practical experience and instruction. The rate of pay should be sufficient to be of material assistance in meeting living and school expenses. The railroad should offer employment to the student each summer during his

university program provided he shows a real interest in his work and demonstrates his capacity to make progress.

Respecting—calling to the attention of universities and colleges such information and conclusions developed by the Association as thought to be of special interest or value to them:

(a) Railway engineering and transportation offer worthwhile opportunities to college and university trained men.

(b) There is an apparent lack of suitable railway transportation text books and a very definite need for texts of an up-to-date nature embodying recent economic developments in construction, operation, and maintenance.

(c) Contrary to the views held by a few, there is every reason for placing confidence in the future of the railways and an equal degree of confidence may be placed in his future by the young man who associates himself with the railway industry.

(d) The work of the AREA as developed in the Manual has been made available to engineering colleges and universities and the majority use the Manual regularly.

(e) It is regretted that a few outstanding colleges or universities have discontinued or curtailed their courses in railway transportation.

Respecting—developing means of bringing to the attention of railway managements the value of a technical education as a qualifying factor for young men desiring to enter railway service with a view to advancement:

(a) Railway officers will find it advantageous to give employment, training, encouragement and opportunity to desirable college men, and thereby create a reserve from which to draw future supervising officers. The adoption of this practice, as a fixed policy, will assist in meeting competition of other transportation agencies, and in keeping abreast of other industries.

(b) A desirable college man is one who, in addition to his educational qualifications, has high character, loyalty, initiative and analytical ability, is a natural leader and organizer, is both aggressive and willing to take and execute orders and is not above starting at the bottom of the ladder or afraid of hard work. There is a real demand on the part of the railways for desirable college men of the type described to meet the future need of employees qualified for advancement.

(c) The railways have not reflected this demand to the same degree as other industries or to the extent justified, although colleges are prepared to cooperate in supplying the men qualified to meet the demand.

(d) Industries to a greater extent than some railways have developed comprehensive methods of employing college men for the purpose of building up and equipping their organizations to meet the continually changing conditions of the modern and highly competitive industrial world.

(e) A few railways, which have had or now have training systems or student courses for new employees, have been or are able to attract desirable men by this means, and the available records of the trainees, particularly those with technical qualifications, have shown the value of these practices to the railways.

Respecting—stimulating a greater interest in the science of transportation among university and college students and create thereby a greater appreciation of the place of transportation in our national economic structure, cooperating with organizations of university and college students and contributing to their activities in such a manner as may be mutually arranged:

(a) Technically trained young men are not now being attracted to railway service for a career as was true some years ago.

(b) Colleges and universities are not now giving students the education and the view point that best prepare them for railway service.

(c) The discontinuance of courses in railway transportation has been the result of an apparent if not real lack of interest on the part of the railways.

Respecting—developing means whereby facilities of the universities may be made more directly available for research work of the Association and the railway industry by cooperative effort between the staffs of the universities and the committees of the Association:

(a) The value of research has been increasingly recognized during recent years by the railway industry as evidenced by the activities and work of individual railways, of manufacturers of railway supplies and equipment, and of the Engineering and Mechanical divisions of the AAR.

(b) The actual research may be carried out through cooperative arrangements with universities for use of laboratory and other facilities; through the laboratories and test departments of individual railways; through the laboratories of manufacturers of railway supplies and equipment or through industrial research laboratories.

(c) Many engineering colleges have well-equipped laboratories and adequate staffs for carrying on railway research work and these colleges are almost invariably willing to cooperate with the railways.

(d) College research facilities are so located throughout the country as to avoid a concentration of research activities and to permit cooperative relations between railways and nearby colleges as well as specialized research dealing with materials or processes applicable to some particular section of the country.

(e) In many universities research is the function of an engineering experiment station while in others it is frequently administered by a special division of engineering research coordinating the activities of the several departments.

Report of Committee 15—Iron and Steel Structures

J. E. Bernhardt, *Chairman,*
F. E. Bates
J. L. Beckel
E. S. Birkenwald
R. T. Blewitt
R. N. Brodie
A. W. Carpenter
C. H. Chapin
A. B. Chapman
O. F. Dalstrom*
R. P. Davis
H. A. Dise
C. P. Disney
O. E. Hager
G. A. Haggander
Shortridge Hardesty
J. B. Hunley
Jonathan Jones
A. R. Ketterson
B. R. Leffler
H. T. Livingston
H. S. Loeffler
C. T. G. Looney
R. W. Mabe
F. M. Masters
N. W. Morgan
C. T. Morris
C. Neufeld
O. K. Peck
F. J. Pitcher
A. G. Rankin
Albert Reichmann
C. H. Sandberg
O. E. Selby
T. C. Shedd
C. E. Sloan, *Vice-Chairman,*
G. L. Staley
H. C. Tammen
G. H. Trout
F. E. Turneaure
F. P. Turner
R. A. Van Ness
T. M. von Sprecken
J. P. Walton
C. E. Webb
H. T. Welty
C. D. Williams
A. R. Wilson
W. M. Wilson
L. T. Wyly
J. E. Yewell
W. L. Young
Committee

* Died April 13, 1945.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Revision of Specifications for Steel Railway Bridges, Chapter 15 of the Manual, presented for adoption and publication in the Manual..... page 245

2. Specifications for fusion welding and gas cutting for steel structures, collaborating with ASTM Committee A–1 on Steel, and the American Welding Society Conference Committee on Bridges.
   No report.

3. Design of expansion joints involving iron and steel structures.
   No report.

4. Relation between fatigue of metals and bridge design.
   No report.

5. Progress in design of bridge details.
   No report.

6. The shortening of eyebars to equalize the stress.
   No report.

7. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of re-

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leased materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

No report.

The Committee on Iron and Steel Structures,
J. E. Bernhardt, *Chairman.*

Oscar Frederick Dalstrom

Oscar Frederick Dalstrom was born at Wyanet, Ill., August 15, 1871, the son of Anders John and Anna Christina (Jacobson) Dahlstrom (old spelling). He died in the Princeton, Ill., General Hospital April 13, 1945.

Mr. Dalstrom was graduated from the Fremont, Nebr., Normal School in 1895. He was a student in the civil engineering course at the University of Nebraska in 1897 and 1898. He was graduated from the Rensselaer Polytechnic Institute June 18, 1901, with the degree of Civil Engineer.

Mr. Dalstrom taught in district and village schools from 1894 to 1897. After his graduation from Rensselaer Polytechnic Institute in 1901 he began his engineering career as a draftsman for the Pennsylvania Steel Company. From 1902 to 1906 he served successively as shop inspector for the Pennsylvania Steel Company, draftsman for the Scherzer Rolling Lift Bridge Company, draftsman for the Riverside Bridge Company of Martins Ferry, Ohio, and again as draftsman for the Pennsylvania Steel Company.

In 1906 Mr. Dalstrom saw greater opportunities on the railways of the Middle West and entered upon his major career—35 years of railroad service with the Chicago & North Western Railway. He was successively: Draftsman, 1907 to 1909; chief draftsman, 1909 to 1917; and engineer of bridges, 1917 until the time of his retirement on August 31, 1941.

In the capacity of engineer of bridges, Mr. Dalstrom displayed an untiring zeal and devotion to duty, and was highly respected for his technical ability, as well as for his attention to matters of detail. One of the larger improvements carried out under his direction was the replacement in 1923 of the three 330-ft. steel truss spans of the railroad bridge over the Missouri River at Blair, Nebr., with new steel spans of heavier load carrying capacity.

Mr. Dalstrom recognized his obligation to the engineering profession, and responded by taking an active interest in the recognized engineering societies, which did not terminate until his death. He was a member of the American Railway Engineering Association, the American Society of Civil Engineers, the Western Society of Engineers, the American Railway Bridge and Building Association, the Chicago Engineers' Club, and the Rensselaer Polytechnic Institute Alumni Association.

With the AREA, Mr. Dalstrom was an active member of Committee 15—Iron and Steel Structures, until the time of his death. As chairman of the editing subcommittee he had full opportunity to exercise his unusual capacity for the use of precise and correct English. He also served on the Special Committee on Impact. He was a trustee of the Western Society of Engineers, 1917–1920; a member of the ASCE Committee on Bearing Value of Pile Foundations; and a director of the American Railway Bridge and Building Association.

When Mr. Dalstrom retired from the Chicago & North Western in 1941, he looked forward to a period of well earned leisure, and went to Princeton, Ill., to reside near his farms. However, following Pearl Harbor, he was called to duty with the War Pro-

duction Board and accepted the assignment because he wanted to be of service to his country. He spent two years in Washington, from January 1942 until the latter part of March 1944, and enjoyed his work because it gave him a part in the war effort. However, in February 1944, following a major operation, he returned to Princeton on the advice of his doctor.

With an improvement of his health, he resumed his work as a member of Committee 15, besides supervising and planning improvements for his farm, but on March 29, 1945, a sudden illness required him to enter the hospital at Princeton, where he died April 13. In accordance with his expressed wish, he was cremated.

The members of Committee 15 and also of the Association will long remember him for his fine moral character and untiring devotion to his chosen profession, as well as for his amiable spirit which enabled him to take part in technical discussions involving sharp differences of opinion without any trace of acrimony.

Report on Assignment 1

Revision of Manual

O. E. Selby (chairman, subcommittee), T. M. von Sprecken, C. E. Webb.

Specifications for Steel Railway Bridges

The committee recommends the following changes in the Specifications for Steel Railway Bridges:

Distribution of Live Load

204. Revise to read:

(a) Where the track is carried on transverse steel beams without stringers, the portion of any axle load on a single beam shall be as follows:

$$P = \frac{KAd}{S}$$

A = Axle load

P = Load on a beam from one track

d = Beam spacing

S = Axle spacing

$K = 1\frac{1}{8}$ for single track and $1\frac{1}{4}$ for double track.

The effects of eccentricity of track and centrifugal force shall be included.

(b) Timber bridge ties shall be designed on the assumption that the maximum wheel load on a rail is uniformly distributed over three ties, and is applied without impact.

Unit Stresses

301 (d). Revise to read:

(d) Timber Cross Ties

Those specified in the AREA Specifications for Wood Bridges and Trestles.

Fit of Stiffeners

527. Revise the first sentence to read:

527. The bearing ends of stiffeners on beams and girders shall be milled or ground to bear against the flange or else shall be welded to the flange.

Specifications for Erection of Steel Bridges

12. Assembling Steel: Revise the last paragraph (appearing on page 15–98) to read:

Fitting-up bolts shall be of the same nominal diameter as the rivets, and the cylindrical erection pins shall be not less than $\frac{1}{32}$ in. larger.

Report of Committee 30—Impact and Bridge Stresses

C. H. Sandberg, *Chairman,*
E. S. Birkenwald
S. F. Grear
A. R. Harris
Meyer Hirschthal
J. B. Hunley
C. S. Johnson
A. N. Laird
H. T. Livingston
C. T. G. Looney
R. W. Mabe
W. E. Robey
G. E. Robinson
C. E. Sloan
A. B. Chapman, *Vice-Chairman,*
F. E. Turneaure
J. P. Walton
A. R. Wilson
W. M. Wilson
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Tests of viaduct columns, collaborating with Committee 15.

   Progress report, presented as information..... page 248

2. Tests of steel spans with ballasted deck, including spans with precast concrete decks and poured-in-place concrete decks; also tests on ballasted decks with timber floor; particular attention to be given to the damping due to the type of deck and the track ballast.

   Progress report, presented as information..... page 248

3. Tests of dynamic shear in steel girder and truss spans.

   Progress report, presented as information..... page 248

4. Tests of impact in columns and hangers of steel spans.

   Progress report, presented as information..... page 249

5. Tests of rigid frame structures of steel and concrete.

   No report.

6. Analysis of additional data from impact tests.

   No report.

7. Determination of damping factors of steel spans and the variation in amount of damping with change in loading, by means of tests with an oscillator and model tests.

   No report.

8. Determination of stresses and impacts in timber-stringer bridges, collaborating with Committee 7.

   Progress report, presented as information..... page 249

The Committee on Impact and Bridge Stresses,
C. H. Sandberg, *Chairman.*

AREA Bulletin 457, January 1946.

Report on Assignment 1

Tests of Viaduct Columns

Collaborating with Committee 15

The research staff of the Engineering Division, AAR conducted tests on a viaduct at Quincy, Ohio, for the Detroit, Toledo & Ironton Railroad. Strain gage readings were taken on the columns and bracing of:

(a) A single bent, 35 ft. in height supporting a 150-ft. deck truss span and a 45-ft. deck girder span.

(b) A 45-ft. tower, 60 ft. in height, supporting a 150-ft. deck truss, and two 45-ft. deck girder spans.

(c) A 30-ft. tower, 60 ft. in height, supporting deck girder spans 45 ft., 30 ft. and 45 ft. long.

The strain gage readings were secured under a double-headed test train at speeds ranging from 5 mph. to 45 mph. These tests under moving loads were the first ever made in this country on a high viaduct with towers where the strains were measured with reliable instruments, and it is expected that the analysis of the data will provide valuable information as to the dynamic stresses in structures of this type.

Report on Assignment 2

Tests of Steel Spans With Ballasted Decks

During the past season, tests have been made on a 110-ft. through girder span having a ballasted timber floor and a 47-ft. deck girder span having a ballasted timber floor under regular scheduled trains at speeds ranging from 5 mph. to 100 mph. Readings were taken at the center and edges of the top and bottom flanges at the center of the span. Readings were also taken on the 19-ft. floor beams and the 13-ft. stringers of the through span.

Report on Assignment 3

Tests of Dynamic Shear in Steel Girder and Truss Spans

The dynamic shear in the web plates of the 110-ft. through girder span and the 47-ft. deck girder span were measured in connection with the tests made under Assignment 2. Also, at the request of several of the individual railroads, the strains were measured in the main and web members of the following truss spans:

(a) 364-ft. open floor draw span with the timber ties bearing on the lower chord. The test runs were made with a double-headed test train at speeds ranging from 5 mph. to 40 mph.

(b) 150-ft. deck truss span, open floor, bearing on viaduct columns. The test runs were made with a double-headed test train at speeds ranging from 5 mph. to 45 mph.

(c) 136-ft. 9-in. through truss span, open floor. The test runs were made with a single-headed test train at speeds varying from 5 mph. to 50 mph.

(d) 129-ft. 6-in. through truss span, open floor. The tests were made with a single-headed test train at speeds varying from 5 mph. to 55 mph. Readings were also secured under regular scheduled diesel freight locomotives at speeds as high as 60 mph.

Report on Assignment 4

Tests of Impact in Columns and Hangers of Steel Spans

The strains were measured in the columns and hangers of the truss spans in connection with the tests made under Assignment 3. Progress is reported in assembling data on this subject.

Report on Assignment 8

Determination of Stresses and Impacts in Timber Stringer Bridges

Collaborating with Committee 7

The strains were measured in the 8-in. by 16-in. timber ties spanning from lower chord to lower chord of the 364-ft. draw span reported under Assignment 3. Simultaneous strains were measured in 12 consecutive ties. The strains were measured in the floor timbers of the 110-ft. through ballasted timber deck girder span reported under Assignment 2. Simultaneous strains were measured in 12 consecutive floor timbers.

These tests were made to determine the magnitude of the strains and the longitudinal distribution of the axle loads and can be considered exploratory tests for this assignment.

Report of Committee 29—Waterproofing

J. A. Lahmer, *Chairman,*
F. E. Bates
G. E. Boyd
A. C. Copland
A. G. Dorland
J. P. Gallagher
W. G. Harding
L. H. Laffoley
R. L. Mays
F. J. Pitcher
F. P. Turner
G. E. Robinson,
Vice-Chairman,
T. M. von Sprecken
H. T. Welty
C. A. Whipple
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, consisting of recommended changes in the Glossary below.

2. Waterproofing of railway structures.

   Supplemental report on comparative tests of waterproofing asphalts and coal-tar pitches, presented as information..... page 251

   The report your committee submitted in 1945 included a recommendation for the extensive investigation to determine whether it is necessary or desirable to revise current AREA specifications for bitumens. Nothing has been accomplished along this line during the past year because facilities for making necessary tests and other investigations have not been available.

3. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for reclamation of released materials, tools and equipment, collaborating with Committee 3A—General Reclamation of the Purchases and Stores Division, AAR.

   No report.

The Committee on Waterproofing,
J. A. Lahmer, *Chairman.*

Report on Assignment 1

Revision of Manual

J. A. Lahmer (chairman, subcommittee), A. G. Dorland, J. P. Gallagher, G. E. Robinson, H. T. Welty.

Your committee recommends that the following definitions be substituted for those now appearing in the Glossary:

Dampproofing.—The treatment of any surface material to retard but not completely prevent the entrance or passage of any liquid. *29*

Surface Coating.—Eliminate

Waterproofing.—The treatment of a material or structure to prevent the entrance or passage of any liquid. *29*

—Integral.—The incorporation of any material other than the usual ingredients to prevent the entrance or passage of any liquid. *29*

—Membrane.—The application of alternate layers of bitumen and fabric or felt, to form a covering on a surface to prevent the entrance or passage of any liquid. *29*

AREA Bulletin 457, January 1946.

—Metallic.—The application to a surface of a mixture of a metal and a reagent, the chemical reactions of which tend to fill the pores, to prevent the entrance or passage of any liquid. *29*

—Plaster Coat.—The surface application of one or more coats of impervious material in the form of plaster to prevent the entrance or passage of any liquid. *29*

—Pressure.—The process by which a material is forced into the pores and cracks of a structure to prevent the entrance or passage of any liquid. *29*

Report on Assignment 2

Waterproofing of Railway Structures

Comparative Tests of Waterproofing Asphalts and Coal-Tar Pitches

G. E. Robinson (chairman, subcommittee), H. T. Welty.

This is a final report on two sections of the comparative tests of waterproofing asphalts and coal-tar pitches, which had not been completed at the time that the previous report was made, Proceedings, Vol. 45, 1944, page 187.

C. Tests to Determine the Effects of Aging

The outdoor weathering tests, which are described on page 192 and reported at the end of two years on page 197, with comments on page 199, were started October 30, 1941.

These tests were discontinued as of August 1, 1945 and the following comments give the status as of that date.

The last inspection made of these panels indicated that the coal-tar pitches were no longer affording full protection to the panels. The remaining film which had not sloughed off was chalking away freely and cracked down to the metal.

The asphalts were still in fair condition. All panels showed light chalking with shallow checking. The remaining film which had not sloughed off was still affording good protection to the metal. Asphalt panel No. 7-M, which had sloughed very little during the test period and retained a film about ⅛ in. in thickness, showed a normal chalking and very little checking. From the observation, this Panel No. 7-M was in excellent condition at the end of the test and, in opinion of the committee, would have withstood several more years of weathering.

After a period of one year very little further sloughing occurred with the bitumens. The rate of chalking remained about the same as the asphalts up to three years and nine months of weathering. The coal-tar pitches appeared to deteriorate very rapidly

Table 1.—Results.—Outdoor Aging Test From 10–30–41 to 7–30–45

Sample No.	*Material*	*Results*	*Rating*
1–A	Asphalt	A–1, B–2, E–4	5
2–C	Asphalt	A–1, B–2, E–3	4
3–E	Asphalt	A–2, B–3, E–5	6
4–J	Asphalt	A–2, B–3, E–4	5
5–K	Asphalt	A–1, B–2, E–4	5
6–N	Asphalt	A–1, B–2, E–2	3
7–M	Asphalt	A–1, B–1, E–1	1
8–B	Coal-tar pitch	A–4, B–2, C–3, E–8	10
9–F	Coal-tar pitch	A–4, B–2, C–3, E–11	11
10–G	Coal-tar pitch	A–4, B–2, C–3, E–10	11
11–D	Coal-tar pitch	A–4, B–2, C–3, E–6	10

with age. The checking or cracking of the asphalts progressed slightly ahead of the chalking and was, therefore, shallow throughout the entire film down to the metal panels and these cracks became wider up to ⅛ in. with further aging.

In Table 1, the numeral indicates the rating for the particular type of failure indicated by the letter, in which A is for chalking, B for checking, C for cracking, E for sloughing.

D. Water Permeability Test

The water permeability test first reviewed on page 200 of the previous report was started on November 3, 1942. For this test, 11 steel pipes 2 ft. in length and 5⅛ in. inside diameter were obtained and a coarse wire screen was welded over one end of each pipe. This screened end of each pipe was then sealed over by using four moppings of bitumen and three layers of fabric. A water tank and mounting rack were constructed as shown in Fig. 4, page 201 of the previous report, so the steel pipes, when placed in the rack, would have the bitumen coated end immersed in water to a depth of 10 in. This depth of water was maintained constant throughout the test period, giving a pressure of 0.36 lb. per sq. in. The water temperature varied from a low of 67 deg. F. to a high of 81 deg. F.

The results reported are given in Table 2.

Table 2.—Results of Permeability Tests

All of the bitumens afforded a perfect seal, with the exception of bitumen 3–E, an asphalt which gave the following results:

Period	*Amount of Water Passage*
11– 3–42 to 2– 1–43	None
2– 1–43 to 2– 4–43	0.97 gal.
2– 4–43 to 3– 6–43	Trace daily
3– 6–43 to 3–22–43	None
3–22–43 to 4– 3–43	Trace daily
4– 3–43 to 4– 5–43	0.16 gal.
4– 5–43 to 4–19–43	Trace daily
4–19–43 to 4–27–43	1.07 gal.
4–27–43 to 11– 3–43	None

This test was terminated as of October 1, 1945, with all the bitumens showing no permeation.

Conclusions

Your committee has no explanation to offer for the behavior of asphalt No. 3–E under the permeability tests.

The asphalts had not yet reached a point of failure at the end of the outdoor aging test, while the coal-tar pitches were practically useless as a protective material. Of course, it should be borne in mind that this outdoor aging test, where the samples were exposed directly to the full effect of all the elements, including sunlight, is a condition which is more severe than would be encountered in the ordinary use of these materials for waterproofing purposes.

Report of Committee 11—Records and Accounts

H. L. Restall, *Chairman*,
Anton Anderson
F. B. Baldwin
S. H. Barnhart
B. A. Bertenshaw
W. C. Bolin
E. V. Braden
F. R. Brunner
Spencer Danby
V. H. Doyle
J. P. Ferris
D. E. Field
C. C. Haire
H. N. Halper
J. H. Hande
A. T. Hopkins
C. D. Johnson
W. R. Kettenring
E. M. Killough
C. A. Knowles
P. R. Leete
W. M. Ludolph
D. O. Lyle
W. S. McFetridge
O. M. Miles
J. B. Mitchell
H. D. Barnes, *Vice-Chairman*,
B. H. Moore
A. T. Powell
C. P. Richardson
J. H. Roach
H. B. Sampson
F. M. Spiegel
R. H. Stenhouse
D. C. Teal
J. R. Traylor
W. C. Wertenberger
Louis Wolf
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Bibliography on subjects pertaining to records and accounts.
   Progress report, presented as information..... page 254

3. Office and drafting room practices.
   No report.

4. Recommended practice to be followed with respect to maintenance of way accounts and statistical requirements, collaborating with interested committees.
   No report.

5. Construction reports and records.
   No report.

6. Valuation and depreciation.
   (a) Résumé of developments of the current year in connection with regulatory bodies and the courts.
   Progress report, presented as information..... page 256
   (b) ICC valuation orders, reports and records.
   No report.
   (c) Development of service lives and rates for depreciation accruals.
   Progress report, presented as information..... page 258
   Appendix A—Trends in depreciation practice..... page 259

7. Report upon changes in revisions, and interpretations of ICC accounting classifications.
   Progress report, presented as information..... page 271

8. Methods for avoiding duplication of reports and for simplifying and coordinating work under the requirements of the ICC and other public authorities.
   Progress report, presented as information..... page 272
   Exhibit A—AAR report on analysis of statistical information.....page 273

AREA Bulletin 457, January 1946.

9. Records of property leased and available for lease.

No report.

10. Style to be used in the preparation of reports, specifications and other documents.

No report.

THE COMMITTEE ON RECORDS AND ACCOUNTS,
H. L. RESTALL, *Chairman.*

Report on Assignment 2

Bibliography on Subjects Pertaining to Records and Accounts

V. H. Doyle (chairman, subcommittee), Anton Anderson, B. A. Bertenshaw, E. V. Braden, F. R. Brunner, H. N. Halper, A. T. Hopkins, W. M. Ludolph, C. P. Richardson, R. H. Stenhouse, Louis Wolf.

This report is submitted as information.

The committee presents the following bibliography of subjects pertaining to railroad records and accounts for the period November 1944 to November 1945.

Pamphlets

1. Industrial Property Records for Accounting and Valuation Uses. By C. V. Armstrong. Published by the Iowa State College Press. Price gratis.

2. Railroad Construction Indices. Compiled by the Engineering Section of the Bureau of Valuation, ICC, Washington, D. C., 11 mimeographed pp., August 1, 1945. Includes map showing division of the country into regional groups for which indices have been established.

3. Railroad Construction Guide Prices. Compiled by the Engineering Section of the Bureau of Valuation, ICC, Washington, D. C., 60 mimeographed pp., October 1, 1945. Includes map showing the eight regions into which the country has been divided for statistical purposes.

Articles

1. Fallacy of Retroactive Depreciation. By D. Gunn. Public Utilities, 34:503–7, October 12, 1944.

2. Modern Trends in Railroad Operating and Accounting Controls. By E. H. Buncll. Savings Bank Journal, pp. 11–13, November 1944.

3. Accelerated Depreciation of Structures urged by the Executive Committee of the Associated General Contractors of America. Engineering News Record, 133: pp. 92, December 14, 1944.

4. Commissioner Smith Hits Critics. Public Utilities, 34: pp. 771–2, December 7, 1944. A defense of the N.A.R.U.C. committee's report on depreciation.

5. Depreciation Allowance Liberalized. By H. J. Asche. Inland Printer, 114: pp. 83, December 1944.

6. Charting Depreciation Data. By H. J. Dow. Railway Age, 118: pp. 239–240 January 27, 1945.

7. The N.A.R.U.C. and Depreciation. By G. O. May. Journal of Accountancy, 79: pp. 34–38, January 1945.

8. Accountants on Depreciation. Economist, 148: pp. 87, January 20, 1945.

9. Are Depreciation Reserves Available for Improvements? By R. J. Meigs. Public Utilities, 35: pp. 46–49, January 4, 1945.

10. Depreciation Fund Problems. By L. R. Nash. Public Utilities, 35: pp. 144–154, February 1, 1945.

11. U. S. Bureau of Internal Revenue Depreciation Rate Schedule. Engineering News Record, 134: pp. 105–164, April 5, 1945.

12. Depreciation and Business Expansion. By F. S. Blackall, Jr. New England War Bulletin, page 3, April 1945.

13. Further Comments on the 1944 N.A.R.U.C. Report. By S. Ferguson. Journal of Land and Public Utilities Economics, 21: pp. 181–184, May 1945.

14. Depreciation and Interest on Capital. By S. H. Whitey. Electrician, 134: pp. 399–401, May 4, 1945.

15. Is Tax System a Bar to Employment? By F. S. Blackall, Jr. Credit and Financial Management, 47: pp. 7–10, June 1945.

16. Post War Readjustments of Property Accounting. By A. B. Hossack, N.A.C.A. Bulletin, 26: pp. 947–957, June 15, 1945.

17. An Engineering Viewpoint on Depreciation Accounting. By E. L. Grant and P. T. Norton, Jr. Journal of Accountancy, 79: pp. 451–455, June, 1945.

18. Defining Depreciation and Accounting for Depreciation. By D. R. Scott. Accounting Review, 20: pp. 308–315, July, 1945.

19. Correct Depreciation Rates Will Help Post War Success. By F. Merish. Textile World, 95: pp. 121, July, 1945.

20. The Failure of the Unit Summation Procedure as a Group Method of Estimating Depreciation. By B. F. Kimball. Econometrica, 13: pp. 225–244, July, 1945.

21. Mortality Characteristics of Physical Property Based upon Location Life Table and Re-Use Ratios. By C. B. Benson and B. F. Kimball. Econometrica, 13: pp. 214–224, July, 1945.

22. On the 1944 N.A.R.U.C. Report on Depreciation. By E. W. Moorehouse. Journal of Land and Public Utilities Economics, 21: pp. 282–286, August, 1945.

23. Depreciation: Graveyard of Dividends. By J. L. Trecker. National Machine Tool Builders Association, page 10, reprint from American Machinist, August 2, 1945.

24. Reappraisal of Depreciation and Obsolescence. By M. S. Massel. Harvard Business Review, 24: pp. 85–95, Autumn, 1945.

25. Association of American Railroads' Joint Committee Report on Analysis of Statistical Information Relating to Operating Cost Useful for Managerial Purposes. 53 mimeographed pp.

Report on Assignment (6a)

Résumé of Developments of the Current Year in Connection With Regulatory Bodies and the Courts

F. B. Baldwin (chairman, subcommittee), H. D. Barnes, S. H. Barnhart, B. A. Bertenshaw, V. H. Doyle, D. E. Field, C. C. Haire, H. N. Halper, A. T. Hopkins, W. R. Kettenring, C. A. Knowles, P. R. Leete, D. O. Lyle, O. M. Miles, B. H. Moore, H. L. Restall, J. H. Roach, H. B. Sampson, R. H. Stenhouse, H. C. Wertenberger.

Property Records and Reports

The property records and reports built up as a consequence of the federal valuation work have been put to many purposes during the year. They have enabled the preparation of depreciation schedules required for corporate accounting needs and have obviated the necessity for filing voluminous schedules proposed as an Interstate Commerce Commission accounting regulation showing service lives and salvage values for roadway property. They have afforded the means for determining the depreciation base and rates of depreciation, both for accounting and income tax purposes. From these records and reports determinations were made of past accrued depreciation required by accounting regulations in the cases of acquisitions, reorganizations, consolidations and mergers. All of these uses are aside from constant daily use in determining ledger values for retirements, leases, joint use and sales of property to or from others and in ad valorem tax and insurance schedules.

The property records thus being made currently, pursuant to ICC orders under the administration by the Bureau of Valuation, have not only made practical the compliance with certain accounting orders of the commission and requirements of the bureau, but have made such compliance possible with a minimum of expense to the railroads. Greater utilization of these records as a matter of economy both to the commission and to the railroads depends largely upon keeping the records and reports of the railroads and the Bureau of Valuation up to date.

The ICC basic appropriation for the fiscal year beginning July 1, 1945, includes $388,319 for its Bureau of Valuation, a reduction of $111,681 from the $500,000 for the previous year. On October 1, 1945, the total force of the bureau numbered 108 employees, or 13 less than last year. The reduction in force was made necessary by the reduced appropriation. Your subcommittee believes that the work of the Bureau of Valuation is of continuing importance in keeping the commission factually informed.

The carriers' annual reports on B.V. Form No. 588 contain the details of property changes from which the Bureau of Valuation brings its previous inventories of the railroad properties to later dates. From the same reports the bureau is enabled to keep an up-to-date record of the original cost of the properties. As of October 1, 1945, although a shortage of help because of war activities caused some delay in these annual reports, practically all carriers had filed reports through 1941, 96 percent were completed through 1942, and 88 percent were completed through 1943, 14 percent had filed reports for 1944. The Bureau of Valuation field check of these reports was 90 percent* current.

According to the records of the Bureau of Valuation, its engineering section having completed revised inventories for all carriers through 1927, is engaged in bringing their inventories forward to later dates, and as of October 1, 1945, were approximately 67

* Based on 7,000,000 mile years from basic valuation dates through 1944.

percent* current. The work of the accounting section in making summaries of original cost other than land is 90 percent* current, and the statement of original cost of Land is 29 percent* current. The land section in its work of revising land valuations to current dates has completed 75 percent* of its work.

No tentative valuations as of current dates were completed and served on railroad companies, but, at the request of the commission, the bureau brought to date the underlying valuation estimates of carriers involved in reorganization proceedings and other cases. Opportunity is afforded the carrier to check these estimates of original cost, the cost of reproduction new, the cost of reproduction less depreciation, and land values, but in only a few instances have the carriers made a check of the bureau's findings.

Most carriers have participated with the engineering section in the work of bringing their engineering reports to current dates when their report is reached in the bureau's program. This affords an opportunity to check the figures, and at the same time, to secure a carbon copy of the detail pencil sheets which show the cost based on 1910–14 prices and depreciation elements on BV Form 643 upon which the information is collected.

Court Decisions

No outstanding valuation cases were decided by the U. S. Supreme Court during the year. Two cases in lower courts are reviewed because of their bearing upon problems of methods of determining depreciation.

In the U. S. Tax Court the case of Los Angeles & Salt Lake R. R. Co. v. Commissioner of Internal Revenue, Docket 106462, (4 T.C. No. 76) promulgated January 30, 1945 it was held that a railroad on the retirement method of accounting for depreciation, which in a taxable year retired and wrote off specific assets which had been acquired prior to 1913, was not required to adjust its ledger cost to eliminate depreciation prior to 1913, under Section 113 of the Revenue Act of 1934, which calls for a proper adjustment to basis for depreciation. The opinion held:

> Under the retirement system of depreciation accounting, expenses of maintenance, including restoration and renewals, even though under other systems they might require capitalization (See Bureau of Internal Revenue Bulletin F (1942), p. 7), are deducted as operating costs. These charges, coupled with the deduction of the cost of the item upon its retirement, are considered to be the rough equivalent of other methods of recovering cost through deductions for depreciation. *Central Railroad of New Jersey supra.* It is thus evident that any specific physical property might be the vehicle for expenditures of restoration and renewal which in the case of a growing railroad could well equal or even exceed the depreciation occurring during the same period. * * *
>
> But unless the retirement system is capable of producing a figure which will fairly reflect the March 1, 1913, investment as to both positive and negative figures, we cannot regard it as proper to make an adjustment in one direction recognizing the impossibility of others of a compensating character. It seems to us to follow that it would be inconsistent with the retirement system to call for an adjustment for pre-1913 depreciation and consequently that under the circumstances here present that adjustment is not "proper" and accordingly need not be made.

Petitions for review with assignments of errors have been filed by both parties with the U. S. Circuit Court of Appeals, 2nd Circuit, and that court at the request of both

* Ibid.

litigants has entered an order extending the time to prepare and transmit the record to October 27, 1945.

In a rate case before the Pennsylvania Public Utility Commission, Docket No. 10867, decided January 3, 1945 (Pfeifle v. Pennsylvania Power & Light Co., 57 PUR (NS) 1), the methods for determining accrued depreciation, both by the utility and by the commission's engineers, were reviewed and dismissed with the following conclusion:

> The Commission thus finds before it two depreciation studies, presented by opposing witnesses; one of them wholly dissociated from anything which either we or the courts have recognized as accrued depreciation of property; the other, a compliance with recognized principles in theory, but lacking the factual basis upon which those principles can be given practical application.
>
> We will disregard the end results of both studies. Having informed our judgment by considering those facts and opinions of each witness which appear to be least speculative, the annual retirements of respondent's property as shown in the reports of record, and the experience of electric utilities in this commonwealth, we find that the accrued depreciation applicable to respondent's depreciable electric plant at December 31, 1942, was 15 percent.

The report is lengthy and does not lend itself to a comprehensive review in this subcommittee report, but it is recommended as interesting material in connection with a study of accrued depreciation.

Report on Assignment 6(c)

Development of Service Lives and Rates for Depreciation Accruals

F. B. Baldwin (chairman, subcommittee), H. D. Barnes, S. H. Barnhart, B. A. Bertenshaw, V. H. Doyle, D. E. Field, C. C. Haire, H. N. Halper, A. T. Hopkins, W. R. Kettenring, C. A. Knowles, P. R. Leete, D. O. Lyle, O. M. Miles, B. H. Moore, H. L. Restall, J. H. Roach, H. B. Sampson, R. H. Stenhouse, H. C. Wertenberger.

Your subcommittee in its 1944 report, Proceedings, Vol. 45, 1944, page 215, called attention to the provisions of the ICC Accounting Orders establishing depreciation accounting for roadway property, under which carriers were relieved, until six months after the close of the war, of the requirement of filing schedules showing their estimates of service lives based on mortality studies and engineering judgment. These permissive requirements were embodied in the Bureau of Accounts Depreciation Section Series Circular No. 10a dated October 15, 1942.

In recognition of the fact that a substantial portion of the information required to make such studies has already been furnished by the carriers in their reports to the Bureau of Valuation, where it can be readily analyzed and collected if needed, the director of the Bureau of Accounts issued a memorandum to all operating steam railroads, dated October 5, 1945, which reads as follows:

> In re: Depreciation Section Series Circular No. 10a, October 15, 1942.
>
> This refers to the third complete paragraph on page 2 of circular No. 10a which reads as follows:
>
> > Unless and until the carrier's estimates of composite annual percentage rates have been computed and filed with the commission, it shall use the

percentage rates obtained from the Bureau of Valuation. It follows that carriers which elect to continue the use of such rates shall not, until six months after the end of the war, be required to submit returns to this circular other than Schedule 1, which should be filed not later than March 1, 1943.

For the benefit of carriers which desire to continue the use of rates obtained from the Bureau of Valuation, the portion of the foregoing which reads "until six months after the end of the war" is hereby suspended until further notice. This relieves carriers of the necessity for submitting complete returns to Circular No. 10a so long as they continue to use the rates furnished by the Bureau of Valuation.

The above circular will relieve the carriers of submitting to the commission any detailed studies of service lives and salvage values so long as an individual carrier is satisfied with the rates furnished by the Bureau of Valuation and now in use.

Representatives of your committee participated with a subcommittee of the General Committee, Accounting Division, AAR, in the preparation of a report dated June 23, 1945, entitled "Trends in Depreciation Practices" which was issued and distributed to carriers by the Accounting Division under date of July 13, 1945. A copy of this report is included herewith as Appendix A.

Under the general subject of depreciation, the subcommittee continued its investigation and study of standard forms that may be desirable for recording changes in the depreciation base, depreciation reserves, and depreciation rates and is of the opinion that due to the variation in requirements of the individual carriers, no standard form can be designed at this time.

Appendix A

Trends in Depreciation Practices

Item No. 27, General Committee
Minutes, June 28–29, 1945.

June 23, 1945

Mr. Eric A. Leslie, Chairman,
General Committee, AAR
Accounting Division,

Referring to the action of the General Committee, at its meeting held in New York on June 28, 1944, authorizing the appointment of a subcommittee to consider the following matters, and to your appointment of the undersigned as members of the subcommittee.

ICC Bureau of Accounts Subject No. 364 (Revised 12/15/44)—Proposed Accounting Order modifying General Balance Sheet Account No. 701, Road and equipment property, and creating an additional Account 701½, Property adjustment, to state expenditures for road property on an original cost basis, as computed by the Bureau of Valuation.

Trends in Depreciation Practices

Both of these matters have been considered by your subcommittee. This report relates to Trends in Depreciation Practices. A separate report is being made on ICC Bureau of Accounts Subject No. 364.

ICC Accounting Regulations Covering Depreciation Accounting

Before entering into a discussion of Trends in Depreciation Practices, it seems desirable to summarize depreciation procedure with respect to railroad property under ICC Accounting Regulations. The establishment of formal depreciation charges was first required under the Classification—Third Revised Issue, effective July 1, 1907, which related only to equipment, and provided that depreciation accruals be based on cost and on a unit basis. In the Classification—Issue of 1914, effective on July 1, 1914, depreciation accounts were prescribed for current depreciation on fixed improvements, which provided that until further directed the recognition in Operating Expenses of current depreciation on fixed improvements was optional. Such depreciation charges were to be based in each instance upon the percentage of original cost (estimated if not known), ledger value, or purchase price of the property determined to be equitable by the carriers' experience and best sources of information as to the actual current loss from depreciation, and the accounting to be on a unit basis.

Section 20, paragraph (5), of the Interstate Commerce Act, as amended by the Transportation Act, 1920, required that:

> The commission shall, as soon as practicable, prescribe, for carriers subject to this act, the classes of property for which depreciation charges may properly be included under operating expenses, and the percentages of depreciation which shall be charged with respect to each of such classes of property, classifying the carriers as it may deem proper for this purpose. The commission may, when it deems necessary, modify the classes and percentages so prescribed.
>
> The carriers subject to this act shall not charge to operating expenses any depreciation charges on classes of property other than those prescribed by the commission, or charge with respect to any class of property a percentage of depreciation other than that prescribed therefor by the commission. No such carrier shall in any case include in any form under its operating or other expenses any depreciation or other charge or expenditure included elsewhere as a depreciation charge or otherwise under its operating or other expenses.

The above paragraph has, by amendment of the Interstate Commerce Act, been somewhat changed in wording and is now paragraph (4) of Section 20 of the Interstate Commerce Act.

Pursuant to this direction, the commission issued the following reports and orders, which are listed chronologically:

(a) Report on Depreciation Charges of Steam Railroad Companies, No. 15,100, August 23, 1923.

(b) Report and Order—Depreciation Charges of Steam Railroad Companies, No. 15,100, decided November 2, 1926.

(c) Proposed Report—Depreciation Charges of Steam Railroad Companies—(Commissioner J. B. Eastman) August 15, 1929.

(d) Report and Order—Depreciation Charges of Steam Railroad Companies—No. 15,100, decided July 28, 1931.

The report and order decided July 28, 1931, item (d) above, were issued after extended hearings and provided that, for the assistance of the commission in prescribing composite annual percentage rates to be effective beginning January 1, 1933, each operating steam railroad company, file with the commission, not later than September 1, 1932, estimates of said percentage rates applicable to ledger values of the respective

primary accounts covering the classes of property specified, and other data. Compliance with this order was postponed from time to time until 1934, when the commission, by order dated June 13, 1934, effective January 1, 1935, amended the classification so as to provide for depreciation accruals on equipment on a group basis, at annual rates prescribed by the commission based on the carriers' estimates computed in accordance with the Order of July 28, 1931. After submission of elaborate data by the carriers, the commission, by sub-orders, prescribed, for each carrier, annual depreciation rates for each class of equipment, which rates, unless modified in the meantime, are currently in effect.

No action was taken with respect to depreciation on roadway property until the year 1941, when the commission issued a proposed Road Property Depreciation Accounting Order, which it planned to make effective January 1, 1942, and which provided for accrual of depreciation on the so-called Track accounts, as well as other classes of fixed property. Based on objections by the carriers, the effective date of the order was deferred until January 1, 1943. In the meantime, the commission, on January 19, 1942, issued an order, effective January 1, 1942, permitting each carrier to accrue depreciation on fixed improvements on a group basis, if it so elected.

On June 8, 1942, the commission issued an order, in Docket No. 15100, effective January 1, 1943, making mandatory the accrual by all railroads of depreciation on depreciable roadway property. The track accounts and roadbed grading were not classed as depreciable property. This order provided that the charges for currently accruing depreciation shall be computed in conformity with the group plan by applying to the original cost, or the estimated original cost of road property as found by the Bureau of Valuation, such percentage rates as will distribute the service value upon the straight-line method in equal annual charges to operating expenses or other accounts during the estimated life of the property. There was no mandatory requirement for setting up any unrecorded depreciation existing as of the effective date of the order. The road accounts considered as depreciable by this order were:

5	13	18	21	24	29	37
6	16	19	22	26	31	44
7	17	20	23	27	35	45

By order dated October 6, 1944, effective January 1, 1945, there were to be included in the depreciation base amounts included in Account No. 1, Engineering, applicable to other depreciable accounts, and, in addition, the depreciable property in Accounts Nos. 2½, Other right-of-way expenditures, 3, Grading, and 39, Public improvements—construction.

Order of the ICC dated September 22, 1941, effective January 1, 1942, required the inclusion in operating expenses of amortization charges accrued during the accounting period for road property and equipment, with respect to which the carrier has elected to observe amortization accounting for income tax purposes under Section 124 of the Internal Revenue Code; the charges so included to be in conformity with the allowances acceptable by the Bureau of Internal Revenue under the regulations prescribed by it.

From the foregoing summary of ICC Accounting Regulations covering depreciation accounting, it is apparent that they are firmly premised upon the following:

On the group basis as distinguished from the unit basis.

On the straight-line method as distinguished from the sinking-fund and annuity methods.

On basis of terms of life (estimated service lives) rather than in terms of use.

On basis of original cost, or estimated original cost as found by the Bureau of Valuation, rather than on basis of fair value.

Recent Trends

Depreciation has been defined as follows:

By the Supreme Court of the United States, Lindheimer v. Illinois Telephone Company, 292 U. S. 151, 167 (1934).

> Broadly speaking, depreciation is the loss, not restored by current maintenance, which is due to all the factors causing the ultimate retirement of the property. These factors embrace wear and tear, decay, inadequacy and obsolescence.

By the Interstate Commerce Commission in Report and Order dated July 28, 1931, in Docket No. 15100.

> Depreciation is the loss in service value not restored by current maintenance and incurred in connection with the consumption or prospective retirement of property in the course of service from causes against which the carrier is not protected by insurance, which are known to be in current operation, and whose effect can be forecast with a reasonable approach to accuracy.

By the Federal Communications Commission, Uniform System of Accounts for Telephone Companies, June 19, 1935 (p. 4).

> "Depreciation," as applied to depreciable telephone plant, means the loss in service value not restored by current maintenance, incurred in connection with the consumption or prospective retirement of telephone plant in the course of service from causes which are known to be in current operation, against which the company is not protected by insurance, and the effect of which can be forecast with a reasonable approach of accuracy. Among the causes to be given consideration are wear and tear, decay, action of the elements, inadequacy, obsolescence, changes in the art, changes in demand and requirements of public authorities.

By the Federal Power Commission and the National Association of Railroad and Utilities Commissioners. Uniform System of Accounts for Public Utilities and Licensees —Federal Power Commission, p. 5. Uniform System of Accounts for Electric Utilities— National Association of Railroad and Utilities Commissioners, p. 3.

> "Depreciation," as applied to depreciable electric plant, means the loss in service value not restored by current maintenance, incurred in connection with the consumption or prospective retirement of electric plant in the course of service from causes which are known to be in current operation and against which the utility is not protected by insurance. Among the causes to be given consideration are wear and tear, decay, action of the elements, inadequacy, obsolescence, changes in the art, changes in demand and requirements of public authorities.

It will be noted that, from the definitions of depreciation as above shown, the Supreme Court and the regulatory commissions have defined depreciation as loss in service value.

The most recent trends in depreciation practices are indicated in the 1943 and 1944 Reports of the Committee on Depreciation of the National Association of Railroad and

Utilities Commissioners, hereinafter referred to as the NARUC report. In these reports, the concept of depreciation is defined as follows:

> Depreciation is the expiration or consumption, in whole or in part, of the service life, capacity, or utility of property resulting from the action of one or more of the forces operating to bring about the retirement of such property from service; the forces so operating include wear and tear, decay, action of the elements, inadequacy, obsolescence, and public requirements. Depreciation results in a cost of service.

It will be observed that the concept of depreciation as set forth in the NARUC report represents a radical departure from the theory of depreciation of the Supreme Court, the ICC and the other regulatory bodies, in that it defines depreciation as "loss in service life," as distinguished from "loss in service value."

The NARUC report also states that the depreciation reserve computed on the basis of "loss in service life" and on the "straight-line" methods represents the "actual existing depreciation," and it therefore follows that the actual past accrued depreciation may be simply computed by applying the straight-line rates to the number of years of expired life. The adoption of the straight-line method in the manner recommended is contrary to the views heretofore held and sanctioned by the courts to the effect that the object of a depreciation reserve is to maintain the integrity of the plant investment, and that such reserve does not necessarily represent the actual depreciation as of a given date.

The NARUC report was widely circulated and was the subject of extended conferences with the public utility experts, American Institute of Accountants, the American Society of Civil Engineers, and others. So far as can be determined, the railroads were not represented. As a result of the criticism which developed and the views submitted by the various groups, the NARUC issued another report, which was known as the 1944 report and which contains some modifications, but the principal findings above enumerated, and which were severely criticized, remain as the basis of the report.

The Committee on Terminology, of the American Institute of Accountants, considered a draft of the 1943 NARUC report prior to its issuance, and, in November 1943, in Accounting Research Bulletin No. 20, included some comments on depreciation accounting which are worth while repeating. It presented a definition of "depreciation accounting" which makes a distinction between "depreciation" as defined by the courts and "depreciation accounting" as a process of accounting procedure. The committee made the important observation that in depreciation accounting the depreciation for the year does not reflect the decline in value during the period, and said:

> The Supreme Court, after defining depreciation, added, "Annual depreciation is the loss which takes place in a year." This statement is not applicable to the term "annual depreciation" as used in accounting.

and defined depreciation accounting as follows:

> Depreciation accounting is a system of accounting which aims to distribute the cost or other basic value of tangible capital assets over the estimated useful life of the unit (which may be a group of assets) in a systematic and rational manner. It is a process of allocation, not of valuation. Depreciation for the year is the portion of the total charge under such a system that is allocated to the year. Although the allocation may properly take into account occurrences during the year, it is not intended to be a measurement of the effect of all such occurrences.

The engineering section of the Bureau of Valuation, of the ICC, is now giving intensive study to the whole subject of depreciation in general, which involves a study of service lives, annual rates of depreciation and determination of past accrued depreciation based upon actuarial studies which in turn are developed from factual retirement data. A series of charts and tables for calculating past accrued depreciation is now being prepared by the Bureau and while the studies are still in a formative stage and incomplete, it is expected that they will be available in due course when completed.

The use by the ICC of "original cost" as the depreciation base conforms to the accounting classifications of various regulatory commissions, such as the Federal Communications Commission and the Federal Power Commission. Support for "original cost" is also indicated in the Supreme Court decision in Federal Power Commission v. Hope Natural Gas Company, U. S. 591 (1944), in which it was stated: "This Court recognized, in Lindheimer v. Illinois Bell Telephone Company, the propriety of basing annual depreciation on cost." The Court went on to say: "We cannot approve a contrary holding in the United Railways v. West."

What Are "Original Cost" and "Original Cost as Found by the Bureau of Valuation?"

Since cost and original cost now play such a large part in depreciation accounting, some comment is in order as to just what is meant by original cost. The term is defined generally as not what the present owners paid for the property, but rather what the first person devoting the property to public service paid for it. It was found by the Bureau of Valuation that only in isolated cases can complete original cost to date be determined from the carriers' records. There then remains "original cost as found by the Bureau of Valuation." The Bureau of Valuation, ICC, in Ex Parte 148, Increased Railway Rates, Fares and Charges, 1942, introduced as Exhibit 12 a Statement of methods employed in the ascertainment of original cost (except Lands and Rights), from which the following is quoted:

> The ascertainment of original cost rests on—
>
> 1. Record or proof of cost of the properties included in the basic inventories and valuations that on January 1, 1940, were still in existence and use;
> 2. Recourse to estimate of original cost for properties that were in existence at the time of original valuation and that were still in existence and use on January 1, 1940, but for which no record or proof of original cost was then or is now available;
> 3. Record of changes that have occurred in the properties subsequent to the date of basic inventory and valuation, reported under oath by the carriers by units and costs, and checked by the Bureau of Valuation engineers and auditors;
> 4. Recourse, in the case of carriers that are delayed in filing their reports of property changes by units and costs for some of the late years, to reports which record changes in dollars only.
>
> The basis for estimates (Paragraph 2 above) is the cost of reproduction new at 1914 normal prices, and follows the commission's conclusion, often stated, that "reproduction cost at normal prices as of 1914, arrived at by consideration of cost data covering periods of five or ten or more years previous to June 30, 1914, produce, by and large, a fair average of the cost of constructing railroads in most parts of the country during these previous years when the great bulk of railway property then in use had come into existence or was brought to modern form."

In Ex Parte 123, Increases in Rates, Fares and Charges, the Bureau of Valuation included the following statement:

> *Development of record of original cost.*—Lack of carriers' record or satisfactory proof of expenditures made it impossible, in most of the original valuations, for the Commission to report actual original cost of all the property owned or used by the several carriers. During the last two decades as a result of reconstruction, additions, retirements, and replacements, aggregating about $18,000,000,000, consisting of $12,000,000,000 in additions and $6,000,000,000 in retirements, the original properties have been substantially changed. In this period, the carriers have been required under the Commission's Valuation Order No. 3 to keep records of such changes and their cost, which are verified in the field by auditors and engineers of the Bureau of Valuation. The result has been that cost may now be stated for a much greater proportion of the properties than was formerly possible, to the extent that resort to estimates in reporting original cost has been greatly reduced and is constantly narrowing through the retirement of the old property included in the basic valuation inventories. Taking the railroads as a whole, original cost for approximately 70 percent of the property is a matter of record at January 1, 1937.

It appears that no figures have been developed indicating the percentage as of any recent date.

In the order of the commission dated June 8, 1942, requiring all railroads to establish a uniform system of depreciation accounting for certain classes of railroad property, it is provided that, if a carrier submits proof that the actual cost to it of the depreciable road property which it owns or the actual cost to the owner of the depreciable road property which it uses and for which depreciation accounting is required, was substantially different from the original cost figures of the Bureau of Valuation, with the approval of the commission, such carrier may use such actual cost figures as the depreciation base.

While the principles underlying the determination of original cost have been stated by the commission, it has been developed by your subcommittee that the methods employed by the Bureau of Valuation have varied in the past. For instance, where a carrier did not restate the betterment credits, the Bureau of Valuation in some instances made the restatement itself, but in others merely accepted the figures as shown by the carrier on B. V. Form 588's. The same is true with respect to the determination of the cost of the overhead accounts, such as engineering, interest during construction and general expenditures. Since the method employed in the computation involves large sums, it may well be worthwhile for each carrier to arrive at "original cost" in accordance with the general principles as enunciated by the commission and then check the bureau's derivation of such cost.

Past Depreciation—No Provision Made Therefor

In the order of the ICC in Docket No. 15100, decided November 2, 1926, establishing depreciation accounting on roadway property to be effective June 1, 1928, there was a definite requirement with respect to the provision for "past accrued depreciation" in Finding (13) which is quoted as follows:

> We find that in the case of steam railroad companies an estimate should be made, as of the date when the system of depreciation accounting herein prescribed is made effective and in accord with the principles hereinbefore set forth, of the

> past accrued depreciation in the property unprovided for by a depreciation reserve, and that the amount so estimated should concurrently be credited to the depreciation reserve and charged to a suspense account on the assets side of the balance sheet. Such estimates of past accrued depreciation unprovided for shall be made by the carrier, subject to check and revision by the commission.

This finding was criticized at great length by the railroads. Their principal objection, although many others were offered, seems to have been that in many instances the effect of setting up the past accrued depreciation would be to seriously decrease or wipe out the surplus, with consequent impairment of credit. Such a result would not, it was urged, be in any way mitigated by the device of a suspense account, since the amount charged to that account would eventually be liquidated through surplus and investors would recognize the inherent nature of the arrangement. Accordingly, in the report in order dated January 28, 1931, in Docket No. 15100, under which depreciation on roadway property was to be established effective January 1, 1933, this finding was revised to read as follows:

> We find that each carrier, whether steam railroad or telephone, shall, subject to check and revision by the commission and as of the date when the system of depreciation accounting herein prescribed is made effective, make an estimate, in accordance with the principles hereinbefore set forth for the determination of currently accruing depreciation, of the accrued depreciation in the property, such estimate to be broken down into component parts corresponding to such primary investment accounts under the respective classifications for steam-railroad companies and telephone companies as include property hereinbefore found to be depreciable. Such accrued depreciation, to the extent that it is unprovided for by the then existing reserve, may, in the option of the carrier, be credited in whole or in part to the depreciation reserve and concurrently charged to profit and loss.

In the order of the commission dated June 8, 1942, establishing depreciation accounting for roadway property effective January 1, 1943, there was no mandatory requirement for setting up any unrecorded depreciation existing as of the effective date of the order. We find some support for this in the 1943 and 1944 Reports of the Committee on Depreciation of the National Association of Railroad and Utilities Commissioners, from which the following is quoted:

> The committee is not unmindful of the fact that utilities, which in the past followed the retirement reserve method, now have reserves which are less than the present full depreciation reserve requirements. The retirement reserve method may have been applied honestly and with the sanction of the regulatory agency having jurisdiction. The amount of the annual retirement expense may have been included in operating expenses as a cost of service, with no more than this amount allowed in the determination of reasonable rates for utility service. Where such conditions have prevailed, and in the absence of countervailing circumstances, it would appear inequitable now to require the utility to give what might be called retroactive effect to depreciation accounting by charging its surplus in order to establish full depreciation reserve requirements.

This thinking relates to immediate reserve adjustments. The Committee on Depreciation, in the two reports referred to, indicated methods which might be adopted for gradual or prospective reserve adjustments usually through surplus. Support for this is

also indicated in the classifications of the Federal Communications and Federal Power Commissions.

As bearing on the matter of recording past accrued depreciation, attention is directed to the order of the ICC dated August 11, 1944, effective January 1, 1945, which modified the existing instructions with respect to Account 702½A, "Acquisition adjustment," relating to the cost of acquisition of a railway or portion thereof acquired since January 1, 1938, as an operating entity or system, by purchase, merger, consolidation, reorganization, receivership sale or transfer, or otherwise, and provides that:

> Account 702½C, "Accrued depreciation—Road," and account 702½D, "Accrued depreciation—Equipment," shall be credited with such sums that will represent at the date of acquisition the estimated past accrued depreciation of depreciable property included in account 701, "Road and equipment property." Similar sums applicable to depreciable property leased from others shall be credited to account 779, "Accrued depreciation—Leased property," the basis for which shall be (1) the carrier's liability to the lessor, and (2) costs included in account 702, "Improvements on leased property."

and that, in cases where opening entries recording the assets and liabilities pertaining to the properties as defined have already been approved, necessary additional entries to provide for past accrued depreciation of depreciable property up to the current period by debits to Account 702½A shall be submitted promptly to the commission for its consideration and decision. Subsequent to the issuance of this order, Director Crandall, of the Bureau of Accounts of the commission, addressed a letter dated October 4, 1944, to Mr. E. H. Bunnell, vice-president, AAR, relating to past accrued depreciation, which is quoted as follows:

> In re: Past accrued depreciation.
>
> Inquiries regarding the accounting prescribed by the commission's order of August 11, 1944, disclose that there is considerable uncertainty regarding the procedure for setting up reserves for past accrued depreciation on property acquired. The following is written for the purpose of clarifying the intent of the accounting provisions, and I shall appreciate it if you will arrange to have this letter circulated among the chief accounting officers of steam railroads.
>
> At the outset I wish to say that it is not intended that the creation of the reserves for past accrued depreciation shall result in a debit balance to account 702½A, "Acquisition adjustment."
>
> Broadly speaking, there are two classes of transactions in so far as the treatment of past accrued depreciation is concerned. These are:
>
> 1. Where the accounting for the acquisition of the property produces a credit balance in account 702½A sufficiently large to permit the transfer to account 702½C, "Accrued depreciation—Road," and 702½D, "Accrued depreciation—Equipment," of amounts representing past accrued depreciation not previously provided for: The accounting for properties acquired as the result of reorganizations under section 77 of the Bankruptcy Act, and receiverships, largely fall within this category although purchases of property of one railroad by another railroad, consolidations, and mergers, in some instances, might qualify for this group. No problem is involved in such transactions in so far as adding to the reserve is concerned, as it is only necessary to charge account 702½A and credit

accounts 702½C and 702½D with sufficient amounts to cover past accrued depreciation. The method of determining the past accrued depreciation is described hereinafter.

2. Where the accounting for the acquisition of the property produces either an inadequate credit balance in account 702½A or no credit balance at all: Purchases by existing railroad companies of all or a part of the property of other railroad companies largely fall within this category. To the extent that there is a credit balance available in account 702½A, it should be transferred to accounts 702½C and 702½D. The remainder of the depreciation reserves should be provided by charge to account 621, "Miscellaneous debits," providing the credit balance in account 786, "Earned surplus—Unappropriated," is adequate for that purpose. If the credit balance in account 786 is not adequate, or, if in the opinion of the carrier, there is good reason for not using it for this purpose, the facts, together with the reasons for the carrier's position, should be furnished this bureau.

The past accrued depreciation should be computed by applying to the amount of the depreciation base of the depreciable property acquired the rates presently in use in computing depreciation thereon for the number of years of its expired service life (estimated if not known). If the carrier wishes to present an alternative method, which in its opinion is better suited to its properties, I shall be glad to entertain it.

Pursuant to this order and Director Crandall's interpretation of it, some of the reorganized roads have made full provision for past accrued depreciation in their accounts, and others at least to the extent of the credit balance in Account 702½A. If the commission issues the proposed Accounting Order as covered by Subject No. 364, it might conclude that, as a matter of uniformity, similar accounting be observed by the non-reorganized roads.

Depreciation From the Standpoint of Federal Income and Excess-Profits Taxes

For federal income and excess-profits tax purposes, many railroads have made application to the Bureau of Internal Revenue in recent years to change from the retirement accounting basis for roadway property to depreciation accounting. Before permission was granted by the bureau to make the change, the carriers were required to furnish information as to the basis for depreciation by primary accounts, estimated net salvage, expired service life, and estimated normal useful life. Upon approval, the depreciation for tax purposes is computed by the straight-line method, but the bases for certain primary accounts are usually adjusted and depreciation allowed upon same at rates different from those approved by the ICC. The railroads are, therefore, required to keep two sets of depreciation records, with resulting confusion and extra work. The ICC denied requests of carriers for authority to accrue depreciation upon the same basis so as to be in harmony with changes acceptable to the Bureau of Internal Revenue.

Before permission was granted by the Treasury Department to change from retirement to depreciation accounting, the carrier had to irrevocably agree to five terms and conditions, which are, briefly, that: a reserve for depreciation shall be set up as of the date of change-over; the remaining sum to be recovered through depreciation allowances shall be limited to the cost less this depreciation reserve; the change shall have no effect

on taxable income for any year ending prior to the date of change-over; the rates of depreciation agreed upon are subject to modification as subsequent experience may require; and that complete depreciation accounting shall be adopted. The Bureau permitted each carrier to elect one of the following three methods prescribed for computing past accrued depreciation as of the date of change-over, viz.: (1) reconstructing depreciation from the beginning, (2) multiplying the expired life of individual structures or the weighted average ages of the accounts by the respective depreciation rates, (3) reserve of 30 percent of the total depreciable road accounts. Subsequently a sixth condition was imposed, viz.:

> That the reserve for depreciation accrued to the date of the change from Retirement to Depreciation Accounting shall reduce accumulated earnings and profits in the determination of invested capital for excess-profits tax purposes.

It is believed that practically all of the railroads which have changed to the depreciation method found it would be to their advantage and elected to compute past accrued depreciation as equal to 30 percent of the depreciable road accounts. The computation of past accrued depreciation has little or no effect for income tax purposes. However, for excess-profits tax purposes, there is a decided disadvantage. Before an agreement was signed by the railroads consenting to these conditions, the matter was considered by the AAR and a brief dated April 20, 1942, was filed with the Bureau of Internal Revenue objecting to the conditions imposed. The railroads have not been successful, to date, in their attempt to recover any amount for past accrued depreciation. They have not, however, given up with respect to the question of deducting this reserve from surplus for invested capital purposes. Relief was requested by Judge Fletcher, of the AAR, on behalf of all the railroads in the hearings before the Senate Committee on Finance in November 1943, but no favorable action was taken. This matter is now being considered by the Tax Committee of the AAR with the object in view of again advocating relief when general revenue legislation comes under consideration.

In Los Angeles & Salt Lake Railroad Company, Petitioner, v. Commissioner of Internal Revenue, Respondent, 4 T. C. No. 76, Docket No. 106462, promulgated January 30, 1945:

> Petitioner, a railroad on the retirement method of accounting for depreciation, which, in taxable year (1934), retired and wrote off specific assets which had been acquired prior to 1913, *held,* under section 113 calling for "proper" adjustment to basis for depreciation, not required to adjust its ledger "cost" to eliminate depreciation prior to 1913.

The Commissioner of Internal Revenue did not acquiesce in this decision, and, on May 28th, appealed to the U. S. Circuit Court of Appeals for the Second Circuit for review and assignments of error. Confirmation of this decision by the higher courts is of importance to the railroads in two respects, in that, (1) additional deductions may be claimed for retirement losses in all taxable years not barred by the statute of limitations equal to depreciation sustained prior to March 1, 1913, on road property, and (2) it affords an opportunity for a reconsideration of the requirement that a 30 percent reserve be set up to cover past accrued depreciation.

In lieu of depreciation, in recent years the railroads have been recording amortization on their books and deducting same on their tax returns on equipment and roadway property where necessity certificates were granted by the War and Navy Departments or War Production Board. The amortization has been computed over a five-year period,

but upon termination of the emergency the railroads may elect to recompute the amortization over the period of use to the end of the emergency, or discontinue amortization and depreciate the unamortized cost.

Due to the heavy war time use of facilities, it has been considered by many that both fixed property and equipment is being used up at a greater rate than is provided for by the present depreciation accruals on a time basis and that increased allowances or accelerated depreciation should be claimed. It has been the policy of the Bureau of Internal Revenue not to increase or decrease the normal depreciation due to change in use, except in unusual conditions, for several reasons, but principally on the theory that increased repairs ordinarily make good additional wear, and, further, that experience shows that obsolescence, rather than wear, ordinarily determines the time of retirement.

It would be more difficult to substantiate accelerated depreciation on roadway property than on equipment, since time, rather than use, ordinarily governs the life of such property, and the depreciation rates upon same were recently established by the bureau. No case is known of a railroad claiming and being allowed accelerated depreciation on equipment, due to war time use. However, in the event of a proposed reduction in depreciation rates by the bureau, a claim for accelerated depreciation would probably be presented by such carrier. When it is considered that the equipment being amortized will be comparatively new at the termination of the war period and could have been charged off for tax purposes, it may be reasoned that the excess of amortization deductions over actual loss in value offsets accelerated depreciation on other equipment, so that the overall deduction now being allowed may be ample.

General

Of necessity, the foregoing report is lengthy. Because the nature of the subject is controversial, your subcommittee has thought it necessary to historically summarize, for the benefit of all concerned, the requirements of the ICC with respect to depreciation accounting, and to point out the implication of recent trends, as covered by decisions of other regulatory commissions and the courts, as affecting the ICC procedure. It is to be understood that your subcommittee does not endorse many of the theories advocated by the commission with respect to depreciation accounting and particularly with respect to roadway property. The railroad companies have not had enough experience with this phase of depreciation accounting to reach a definite conclusion.

Because of the time and effort spent by your subcommittee in research in connection with the subject of depreciation and trends in depreciation practices, the implication involved in ICC Subject No. 364, and the probable contact which will have to be made with the Bureau of Valuation of the commission in connection with studies which the bureau is making, your subcommittee would be glad to serve as a standing subcommittee of the General Committee to handle matters affecting depreciation accounting.

Because of other engagements, Mr. L. J. Tracy, controller, Union Pacific Railroad, a member of the subcommittee, was unable to participate in the deliberations of the subcommittee and in the preparation of this report.

Respectfully submitted,

T. J. Tobin, comptroller, Erie R.R. Co. (*Chairman*)
R. C. Miller, comptroller, Pennsylvania R.R. Co.
W. F. Kennedy, comptroller, Louisville & Nashville R.R. Co.
F. B. Baldwin, valuation engineer, A.T. & S.F. Ry. Co.
H. D. Barnes, assistant general auditor, C. & N.W. Ry. Co.
H. L. Restall, valuation engineer, Boston & Maine R.R.
J. H. Roach, chief valuation engineer, New York Central System

Report on Assignment 7

Report Upon Changes In, Revisions, and Interpretations of ICC Accounting Classifications

H. D. Barnes (chairman, subcommittee), F. B. Baldwin, S. H. Barnhart, W. C. Bolin, Spencer Danby, C. C. Haire, J. H. Hande, W. R. Kettenring, C. A. Knowles, P. R. Leete, W. S. McFetridge, O. M. Miles, J. B. Mitchell, A. T. Powell, H. L. Restall, C. P. Richardson, J. H. Roach, J. R. Traylor, Louis Wolf.

This is a progress report, submitted as information.

Mr. Bunnell, vice-president, AAR, requested your committee to review ICC Bureau of Accounts Subject No. 374—Proposed Modification of Road and Equipment Instructions of the Uniform System of Accounts to include equipment and the retirement of road and equipment property in the exclusions from capital accounting under the so-called minimum rule. Mr. Bunnell was furnished with a summary of the opinions of the members. This subject was subsequently withdrawn. The committee was also asked for its opinions with respect to the treatment of betterment accounting on the returns to Valuation Order No. 3 and these were also submitted.

The ICC has issued the following orders of interest to engineers since this committee's last report (Proceedings, Vol. 46, 1945, pages 180 to 182).

Order dated December 29, 1944, effective March 1, 1945, revising the texts of Balance Sheet Accounts 761 and 767.

Order dated February 23, 1945, effective April 1, 1945, revising the accounting classifications to require the retirement of an appropriate proportion of general expenditures in connection with road and equipment retirements.

Order dated February 26, 1945, waiving the requirement for an annual inventory in 1945.

Order dated April 20, 1945, prescribing "Regulations to Govern the Destruction of Records of Steam Railroads, Issue of 1945," effective June 1, 1945.

Order dated June 25, 1945, making January 1, 1946 the effective date of depreciation orders dated June 8, 1942 for Class II steam roads and postponing until January 1, 1947 the effective date of such orders for Class III steam roads.

Order No. 29140, dated August 2, 1945, reopened the proceedings with respect to the accounting for driving posts to arrest water pockets and mud heaves previously covered by orders dated May 19, 1944 and March 26, 1945, the respondents being the Texas & Pacific Railway, the Texas & New Orleans Railroad, and the Louisiana & Arkansas Railway. This order broadens the scope of the proceedings to include the accounting for pressure grouting to stabilize roadbeds and names as additional respondents all Class I steam railway companies subject to the Interstate Commerce Act.

Order dated August 3, 1945, effective October 1, 1945, revising the instructions and texts of various operating expense, income and general balance sheet accounts with respect to the current accrual of unaudited items affecting revenues, expense and income accounts.

Order dated October 26, 1945, effective January 1, 1946, revising the text of income account 546, Interest on Funded Debt.

Bureau of Accounts circular, dated October 5, 1945, suspends the requirement in Depreciation Section Series Circular No. 10a, dated October 15, 1942, for the submission of returns to that circular within six months after the end of the war, if a carrier continues the use of rates obtained from the Bureau of Valuation,

In addition to these orders the Bureau of Accounts has released the following new and revised rulings:

Issued January 1, 1945

Case A–178 Specifies the accounting when only 35 percent of the cost of equipment or facilities is certified for amortization.

Canceled March 31, 1945

Case A–168 Prescribed the accounting for labor and materials used to stabilize the roadbed.

Issued October 9, 1945

Case A–179 Prescribes the accounting for the retirement of facilities which have been subject to both depreciation and amortization accounting.

The Bureau of Accounts also issued Accounting Series Circular No. 89, dated March 20, 1945, revising the terminology to modernize cases 59, 89, 109, 135, 156, 175, 239, and 288 contained in Accounting Bulletin No. 15.

Report on Assignment 8

Methods for Avoiding Duplication of Reports and for Simplifying and Coordinating Work Under the Requirements of the ICC and Other Public Authorities

C. A. Knowles (chairman, subcommittee), Anton Anderson, W. C. Bolin, F. R. Brunner, Spencer Danby, J. H. Hande, C. D. Johnson, W. M. Ludolph, D. O. Lyle, W. S. McFetridge, B. H. Moore, F. M. Spiegel, J. R. Traylor.

In the report of your subcommittee which appeared in the Proceedings, Vol. 45, 1944, reference was made to a joint committee organized by the Association of American Railroads and consisting of representatives from the Operating-Transportation Division, the Construction and Maintenance Section and the Accounting Division, for the purpose of a review of reports and statistics generally maintained for managerial purposes. The AREA is represented on that joint committee by a member of your subcommittee.

In the Proceedings, Vol. 46, 1945, the statement was made that the committee had prepared a report which was to be published in the AREA Bulletin for June–July 1945. Due to various circumstances this proposed arrangement was not carried through.

A copy of the report which is captioned, Report of Association of American Railroads' Committee on Analysis of Statistical Information Relating to Operating Costs Useful for Managerial Purposes, is presented herewith as information.

Exhibit A

Report of Association of American Railroads' Committee on Analysis of Statistical Information Relating to Operating Costs Useful for Managerial Purposes

The assignment given to this committee was to suggest ways and means for reducing paper work on the railroads, the underlying thought being that manpower is often wasted in the preparation of statistical and cost data which actually may have little or no value.

An analysis of the assignment revealed three ways by which the subject might be considered:

1. Urge railroads to survey all reports and statements and eliminate those which do not satisfy a specific need.
2. Request copies of all statements prepared by railroads and after analysis suggest the discontinuance of those the committee feels are unnecessary.
3. Review the basic purpose of statistics relating to operating costs and present an analysis of such statistics considered useful for managerial purposes.

The first procedure was dropped from consideration when it was realized that most railroads now review, annually, all statistical statements with that thought in mind.

The second was dropped when it became apparent that the committee would be placed in the position of saying certain specific statements, or parts thereof, were useless.

The third course was decided upon because it is believed that the outcome of a review of the basic purpose of this type of statistical information will bring about a reduction in the amount of these data that is now being furnished with a consequent saving in man-hours. It is hoped that this report will be furnished all those who make use of statistical information in the controlling of expenses. No suggested forms are included in this report for the reason that each officer will require that his forms be set up in accordance with his specific needs.

The statistical and cost data necessary to determine that a property is being efficiently operated should be about the same basically on all railroads.

It is the purpose to review the basic causes for the incurrence of expenses and through this analysis suggest the preparation of statistical statements that will show the measure of success obtained in the endeavor to secure the most economical operation of the railroad. This measurement should be made through a comparison of the cost of material and labor actually employed on a given project with a standard, that is, the material and labor established as being adequate for the job. Too often the final results shown on a statement are valueless because of faults that underlie the final results reported. These faults include distribution errors, the relation of certain items of expense to factors that have no bearing on the expense, etc.

A mass of statistical cost information is produced on the railroads and the production of these statements costs money. If the use of any one of the statements is not to the end of controlling or reducing expenses, then the company's money is being wasted even though the production cost is not chargeable to an account for which the office receiving the report is responsible.

Another purpose of this report is to impress upon the supervisory officers, that the worth of an officer to his company is frequently displayed through appropriate statistics properly prepared. For this reason, if for no other, all officers should be interested in

knowing that the statistics relating to their work are adequate and are accurate enough to reveal the true measure of their personal efficiency and that they are not measured on the basis of a report that consists of an accumulation of unrelated charges that happen to be thrown together because of the manner in which the accounting classification is set up.

The Purpose of Statistics

Useful statistical reports of accomplishments can only be prepared after careful consideration of, (a) the need for the report and the use to be made of it, and (b) the means by which the need can be satisfied.

Having decided that there is a need* and that the use to be made of the information will be of more value to the company than the cost of preparation, it is necessary that a statistical structure be built, and that it be composed only of such elements as definitely have a service and utilitarian value.

The building of a statistical structure may be compared with the building of a physical structure designed and constructed to serve a useful purpose. The strains and stresses that will be imposed upon the physical structure are a matter for advance determination, and future needs should be anticipated so that the finished structure will not become obsolete before its useful life is exhausted.

When designing a bridge the engineers ascertain the volume of traffic to be handled and the weight of locomotives and equipment that must be carried by the bridge. They then determine the material to be used so that all of the elements entering into the structure will be combined into a composite whole with each element performing its function in combination with the others to sustain the load. It would not be economical to provide more material than absolutely necessary. The requirements of such a physical structure can be ascertained on the basis of the experience of the engineers.

Similarly, the use to be made of a statistical structure must be anticipated to avoid the inclusion of unnecessary and nonessential elements which only add to the expense and serve no purpose. The elements that should find a proper place in the statistical structure can be readily determined. Their usefulness can be established in the laboratory of experience and knowledge in the same manner as the elements that enter into a bridge can be appraised as to their durability and strength.

Many existing statistical structures were built in a rather haphazard manner, each individual seeking information, having specified the elements to be used in accordance with his own preconceived notions. It is now proposed that all existing statistical structures be re-appraised and only those be retained which will be of definite assistance.

Preparation of Statistics

Statistical statements are generally prepared in the accounting department of the railroads as that department receives and analyzes the reports of work performed, material used, etc. Those who prepare the statements and reports are not under the direct jurisdiction of the officers responsible for the performance of the work in the field. It is possible, in a small organization, for the one who does the work also to keep the time, prepare the payrolls, assemble information as to material used, etc., and prepare his own statistics. In larger organizations this procedure is not practical and as a consequence the clerical work that might be done by someone on the job is delegated

* One of the major tests to be applied before a decision is made is to ascertain that a report based on past experience will aid in the control of future work so as to bring about more efficient and economical operations.

to a clerk, thus freeing the worker from the necessity of preparing statistical data. The fact that those who prepare the statistical data are not under the jurisdiction of the person who does the work does not mean that the supervisor of the work is relieved of responsibility for the correct distribution of labor and material charges to the accounts but it does mean that this plan of organization is used because it is economical.

The division of labor between those actually performing the work and those recording and reporting the cost and effect of the work is made because such division permits each employee to do a better job on his particular phase of the work than could be done if one individual had to do both jobs. Some railroads employ statisticians in the division offices to prepare such current statistics as are required by the supervisory staff.

There is much comment on the time interval between the actual operating performance and the receipt of statistical reports. This time lag is natural, the length of which depends upon the handlings the basic data have to encounter before they are available for use by the statistician. However, the loss of time that is really the cause of the complaints is largely caused by the desire to prepare statistics as economically as possible. Any statistical information for which there is an urgent need can be furnished as quickly as it is needed, if one is willing to pay the cost that will be incurred because of deviation from a standard procedure. It might seem that no additional cost should be incurred through speeding up preparation of statistics but that is not the case because many times statistical statements are prepared as a byproduct of other accounting work, required by regulation or otherwise. In order to speed up the statistical work, it might be necessary to handle the statistical job separately from the accounting or other work ordinarily done before statistics are prepared.

Use of Statistics

Statistics are the result of the collection and tabulation of facts. Benefit is derived only through the study of the tabulated facts and the analysis can be aided by relating current facts to those for a comparable period. However, even if reports for the current and previous period are available, it is impossible to obtain full benefit from statistics unless one has a full knowledge of the elements underlying them.

The officer using the statistical information compiled from these reports should be on the alert for changes in the underlying data that would result in errors. With knowledge of the basic material used in the comparative statements, the officer is in a position to make real use of the statistics. Without detailed knowledge of the source of the information and how the statistics are prepared, the officer lacks one of the important facts necessary to permit him to utilize properly the information contained in the report.

The collection and tabulation of statistical data are expensive and should be undertaken only when it is known that the report will be of aid and assistance. It should be decided whether this collection of facts should be made periodically or continuously, as the continuous collection of information is more expensive than the periodical collection of such data.

Accuracy is one of the most important factors to be considered when arranging for the collection of information for statistical reports. When forms are prepared for reporting data, they should provide for no more detailed than can readily be gathered by the employee doing the work in the field. If reports are required in considerable detail it may be found less expensive to have clerical employees record the facts. One thing about the collection of data that should be kept in mind is that the employee making the basic report should be thoroughly informed as to the reason for the report. It is certain that the employee will make a better report if he knows what it is for.

Many statements are arranged to compare current statistics with those of previous months of or the same month in the preceding year. In most cases it would be better if the comparison were made with a standard cost (labor and material required to do the job under normal conditions) so that the comparison of current expenses with the standard would reveal how well the job has been done. Such a comparison has value whereas there is little value in a comparison with the costs for a previous period as there is no assurance that the costs previously recorded represented economical practice. Other reasons why such comparisons with previous costs are unsatisfactory are:

1. Cyclical changes that do not follow through in the current period.
2. Emergency conditions affecting one period and not another.
3. Seasonal influences and wide fluctuations in volume of traffic.

When preparing cost reports it should be borne in mind that there are two classes of supervisors for whom reports are made:

General Officers.—Such officers should be provided information grouped by departments for:

1. Determination of policy.
2. Measuring efficiency of supervision.
3. Regulating expense to income.

The reports should be prepared so as to place the responsibility for the expense incurred. It is possible that because of the necessity for satisfying all officers it will not be practical to use strictly standardized forms.

Department Officers.—Reports made to such officers should provide information for:

1. Aiding in the attainment of high standards of efficiency.
2. Providing details of operation.

Obviously each supervisor should be furnished only those statistics that relate to the work under his control and if they contain averages per gross ton-mile, car-mile, etc., the supervisor should understand fully their meaning and value, as without this understanding the supervisor is not in a position to make full use of the information and if he cannot, money is being wasted in the preparation of the report.

If statistics are to be of value to a supervisor, they must be furnished on a relatively current basis, otherwise, they are merely historical and while interesting, will not serve a vital need in conducting current operations.

If statistics are to be valuable:

1. The user should be thoroughly familiar with the basic reports.
2. The user should be familiar with the accuracy with which the basic data are prepared.
3. The reports should include only the information essential to the proper determination of costs that are being studied.
4. The costs reported in statistical statements should agree with costs as revealed in the accounts of the company.

When a statement has outlived its usefulness, that is, when it no longer serves as an aid in the necessary analysis of the function it covers or in the reduction of expenses, immediate steps should be taken for the discontinuance of the report. It should be recognized that the assembly of data for and the preparation of statistical statements that are not used is a wasteful expenditure. Every dollar expended should produce a direct or indirect profit otherwise there is a dissipation of the income derived from the product of the company (transportation service) and this should not be tolerated.

Analysis of Railroad Operations

To ascertain the efficiency with which a railroad is being operated, the results of the operation may be analyzed as follows:

I—Comparison of statistical averages.
II—Comparison of costs.

I—*Comparison of Statistical Averages.*—Dr. J. H. Parmelee, director, Bureau of Railway Economics of the Association of American Railroads, has said that the results of railroad operations may be analyzed for the purpose of ascertaining the efficiency thereof, through comparison of the following statistical averages:

1. Percent of cars and locomotives held awaiting or undergoing repairs.
2. Increased loading of cars.
3. Increased mileage of cars.
4. Ton-miles per car-mile.
5. Ton-miles per car-day.
6. Ton-miles per train-mile.
7. Gross ton-miles per train-hour.
8. Net ton-miles per train-hour.
9. Fuel consumption—freight—pounds per gross ton-mile, including locomotive and tender.
   Passenger—pounds per passenger-train car-mile.
10. Proportion of empty car-miles.
11. Speed of operation—freight and passenger—trains and cars.
12. Miles per locomotive-day (average locomotives in service into locomotive-miles divided by days in the period).

Dr. Parmelee also offers the following as a composite index:

1. Gross ton-miles per train-hour.
2. Percent of serviceable freight cars.
3. Freight train speed.
4. Gross ton-miles per ton of fuel.
5. Freight car-miles per car-day.
6. Net ton-miles per train.
7. Passenger train car-miles per ton of fuel.
8. Percent of serviceable locomotives.
9. Locomotive-miles per locomotive-day.

When using this composite index, a base period should be established as 100; then a separate index number should be computed for each of the nine factors and the nine indices thus derived should be averaged, that is, added together and divided by nine, producing an arithmetical average of the relative indices.

There is still another unit of measure, while not in general use, that is quite important in reflecting the effectiveness of transportation service and economy in the use of equipment in producing that service, namely, the "loaded freight car-miles per car-day of all freight cars." A railroad receives its revenue primarily from the transportation of the lading in the car or loaded cars. The empty car-miles and the movement of equipment incident to the performance of revenue producing service are merely the instrumentalities by which the transportation service is produced and the empty cars are impediments incident to the production of that transportation service.

II—*Comparison of Costs.*—This comparison of costs of performing transportation service may be made in one of two ways:

A. Costs by accounts by departments.
B. Standard costs—costs by units of work performed.

A. Costs by Accounts by Departments

Costs by accounts by departments will only be used until arrangements can be made to employ the more satisfactory of the two measuring costs on the basis of units of work performed (standard costs), but the following will assist in the preparation of statements that will show the comparison of present with past expenses.

The expenses of each period should be related as nearly as possible to the actual cause of the expense to ascertain satisfactorily the explanation of the fluctuations in the expenses of one period compared with another under this plan. Many statements, purporting to analyze such differences and to explain or justify the variations are not prepared with this in mind.

Usually when analyzing expenses one month's expense is compared with the expense of the same month in the previous year. There is nothing to justify using the previous year's expense as the gage by which to criticize this year's costs. It is obvious that it would be better to compare current expenses with a base figure built up from costs of the past five or ten years, adjusted to reflect changes in labor or material costs.

Accounting department representatives should be present at meetings where reports are used by operating or other departments for educational purposes, to obtain an understanding of the actual use made of the information, and to determine what data furnished are unnecessary and what additional information would be of material aid to the officers using the statements.

1. *General or Overall Analysis.*—An analysis should be made of the details reported on the balance sheet, and profit and loss and income statements for the purpose of detecting the broad trends of the business of the company.These trends should be compared with those of other railroads in the same territory. All variations from the general trend should be carefully analyzed. To analyze trends it is necessary to have a full knowledge of the business for the reason that what appears to be a trend may have been brought about by a combination of such factors as:

Trend—underlying growth or decline
Seasonal—customary ebb and flow
Cycle—business tempo

The comparisons between periods and between railroads should be made on the basis of percentages and ratios, for example, percentage relation, classes of assets and liabilities and of income and profit and loss accounts by classes. These comparisons should reveal, for example, changes in the ratio of current assets to current liabilities, cash and receivables to current liabilities, etc.

Current material prices and labor rates should be compared with similar prices and rates for some prior period. To make this comparison more valuable, it would be well to include in the statement material and labor indices, relating current costs to the same base period used in connection with material prices and labor rates.

The comparison of the results of operations should relate expenses to revenues through the medium of operating ratios. This seeming violation of the aforementioned principle that all expenses do not follow revenues is justified, as the comparison of these ratios discloses whether the head of each major department is adequately controlling his expenditures so they are in line with business conditions.

Comparisons of operating ratios between roads or operating divisions are not particularly valuable because different commodities are handled at rates that are not comparable. For example, one territory may produce a large quantity of coal and another grain. If the bulk of traffic handled on one road or division is high rated, the operating ratios may not disclose an inefficient operation.

The operating ratios show the relation of the following general account groups to operating revenues:

Account I—Maintenance of way and structures
II—Maintenance of equipment
III—Traffic
IV—Transportation—rail line
V—Transportation—water line
VI—Miscellaneous operations
VII—General

To analyze the fluctuations in expenses under these groups of accounts it is necessary to understand the charges included therein and the cause of the expenses. It can be said that, as a general thing, charges to these accounts are made up of the following items:

Labor—Railroad employees
Material
Miscellaneous
Payment for services of other than railroad employees
Claims
Work-train expense
Shop expense
Stationery, printing, power, light, etc.
Depreciation and retirements

2. *Maintenance of Way and Structures (Account I).*—It is important that statements reflecting maintenance expenses bear a notation of changes in maintenance policy or program if such change would affect costs.

Maintenance expenses seem to follow revenues for the reason that when revenues increase, the program of work to be done is increased, or vice versa; for example, the revenues of Class 1 railroads dropped 43.5 percent from 1928 to 1935 and expenses in the same period fell 41.5 percent.

It follows that since the requirement for maintenance has no fixed relation to revenues it should not be related to revenue statistics. Natural deterioration causes a large part of maintenance expense, so, although maintenance expenses may vary with the revenues, the wear and tear occasioned by transporting the increased business is not the sole cause of an increase in those expenses. That a large proportion of maintenance expense is not attributable to use is shown by the fact that the so-called Yager formula assigns only one-third of maintenance of way and structures expenses to use.

The analysis of fluctuations in maintenance of way and structures expenses may be facilitated by grouping the related individual accounts for overall comparison and then analyzing only individual accounts in the groups showing large fluctuations.

Grouping of accounts as follows should prove satisfactory:

(a) Roadway Maintenance and Repairs (direct)
Account 202—Roadway maintenance
212—Ties
214—Rails
216—Other track material
218—Ballast
} Divided between programmed replacements and running expenses
220—Tracklaying and surfacing
221—Fences, snowsheds and signs
269—Roadway machines
271—Small tools—supplies
272—Removing snow, ice and sand

(b) Tunnels, Bridges and Elevated Structures (direct)
Account 206—Tunnels and subways
208—Bridges, trestles and culverts
210—Elevated structures
281—Right of way expenses

(c) Buildings and Other Structures (direct)
Account 227—Station and office buildings
229—Roadway buildings
231—Water stations
233—Fuel stations
235—Shops and engine houses
237—Grain elevators
239—Storage warehouses
241—Wharves and docks
243—Coal and ore wharves
265—Miscellaneous structures

(d) Signals (direct)
Account 247—Telegraph and telephone lines (overhead)
249—Signals and interlockers

(e) Power Plant and Transmission Systems (direct)
Account 253—Power plants
257—Power transmission systems

(f) Joint Facilities (direct)
Account 278—Maintaining joint tracks, yards, and other facilities—Dr.
279—Maintaining joint tracks, yards, and other facilities—Cr.

(g) Supervision and Miscellaneous (overhead)
Account 201—Superintendence
268—Deferred maintenance—way and structures
273—Public improvements—maintenance
274—Injuries to persons
275—Insurance
276—Stationery and printing
277—Other expenses
280—Equalization—way and structures

(h) Depreciation (overhead)
Account 266—Road property depreciation
267—Retirements road

270—Dismantling retired road property
270½—Road amortization of defense projects

It has been found that it is practically impossible to devise a statistical unit that will show how much work is performed as maintenance of way and structures but the United States Railroad Administration established equation factors, to weight tracks being maintained by divisions, as follows:

Main track	1.0
Other main	0.8
Yard and siding	0.5

Repair and roadway maintenance charges may be satisfactorily compared between divisions by this method.

It is not possible, with the present distribution of charges, to develop actual unit costs for installing ties, rails and ballast. Unit cost studies should, however, be made from time to time for the purpose of comparing costs of applying ties, rails and ballast.

Man-hours and material applied may be related to assist in the explanation of certain variations. Man-hour comparisons should be by divisions or districts and if possible, by accounts, although it must be remembered that these data will not disclose how much actual work was done. Material applied will more nearly indicate how much work was done, but roads charging out material "as issued" will not be able to use this unit but will have to rely on observations of supervisors to be certain that man-hours are not wasted.

To analyze satisfactorily the expenses, except supervision and joint facilities, requires the separation of charges to those accounts between labor, material, miscellaneous and retirements. The labor and material charges must be adjusted to reflect differences in wage rates and material prices if any significant changes have taken place between the periods being compared. The analysis of supervision expenses should be made by studying fluctuations in force and rate changes. Joint facility expense fluctuations can only be analyzed after a study of the bills and vouchers which reflect the use of the facilities.

The work done on track sections such as ditching, cleaning right-of-way, mowing, cutting weeds and track walking cannot be allocated on any unit basis. It seems desirable to have this work done on the basis of inspection reports and the assignment of work by roadmasters or track supervisors. In other words, after inspection, a money allotment should be given section foremen to be spent in ditching, cleaning, cutting weeds, etc. This would, in effect, be a budget for such work as cannot be related to specific units.

3. *Maintenance of Equipment (Account II).*—Use of equipment is the cause of the greater proportion of the maintenance charges (approximately 75 percent); therefore, it follows that satisfactory comparisons may be made by relating expenses per locomotive-mile, per car-mile, etc., of one period with those of another selected period. As in the case of maintenance of way and structures accounts, it may be desirable to group these accounts as follows to reduce the number of variations to be analyzed:

(a) Motive Power Repairs (direct)
Account 308—Steam locomotives—repairs
311—Other locomotives—repairs

(b) Equipment Repairs Other Than Motive Power (direct)
Account 314—Freight train cars—repairs
317—Passenger train cars—repairs
323—Floating equipment—repairs

326—Work equipment—repairs
328—Miscellaneous equipment—repairs

(c) Supervision and Miscellaneous (overhead)
Account 301—Superintendence
332—Injuries to persons
333—Insurance
334—Stationery and printing
335—Other expenses
338—Equalization—equipment
339—Deferred maintenance—equipment
340—Major repairs—equipment

(d) Shop and Power Plant (overhead)
Account 302—Shop machinery
304—Power plant machinery

(e) Depreciation and Retirements (overhead)
Account 305—Shop and power plant machinery—depreciation
306—Dismantling retired shop and power plant machinery
329—Dismantling retired equipment
330—Extraordinary retirements—equipment
331—Equipment—depreciation
331½—Equipment—amortization of defense projects

(f) Joint Facilities (direct)
Account 336—Joint maintenance of equipment expenses—Dr.
337—Joint maintenance of equipment expenses—Cr.

The expenses in these accounts should also be separated between labor, material and miscellaneous. In this group, miscellaneous includes shop expense which should also be analyzed by separation between labor, material, etc. If labor rates or material prices have changed substantially between the periods being compared, the affect of the change on the fluctuation should be taken into consideration.

Locomotive repairs expense is generally related to run off miles although deterioration is also a factor in creating this expense. If general repairs are made by fixed classes and general and running repair expenses are kept separate, classified repairs are a desirable unit for comparative purposes.

Freight train car repairs are difficult to analyze because included in the expenses are the costs of repairs to home cars on foreign lines, billed at AAR prices; credits for repairs to foreign line cars, at AAR prices; and the cost of foreign cars destroyed. Man-hours and material applied seem to be the only satisfactory units for comparison as no other satisfactory statistical yardstick is available.

Supervision costs should be analyzed by a study of forces and rates of pay.

Joint facility debits and credits must be analyzed by a study of bills and vouchers.

Maintenance and depreciation of work equipment may be considered with maintenance of way and structure expenses when certain investigations are being made, but there seems to be no reason for doing this when analyzing fluctuations.

4. *Transportation—Rail Line (Account IV).*—Fluctuations in transportation expenses will more nearly follow revenues, although passenger expenses will not follow passenger revenues as closely as freight transportation expenses follow freight revenues for the reason that passenger train schedules are fixed, whereas, freight train service is more closely attuned to volume of freight traffic.

If a regrouping of the accounts is found desirable before starting the analysis of these expense accounts, the following grouping may prove satisfactory.

(a) Train and Locomotive Service (direct)
Account 392—Train enginemen
393—Train motormen
394—Train fuel
395—Train power produced
396—Train power purchased
397—Water for train locomotives
398—Lubricants for train locomotives
399—Other supplies for train locomotives
400—Enginehouse expenses—train
401—Trainmen
402—Train supplies and expenses

(b) Yard Service (direct)
Account 377—Yardmasters and yard clerks
378—Yard conductors and brakemen
379—Yard switch and signal tenders
380—Yard enginemen
381—Yard motormen
382—Yard switching fuel
383—Yard switching power produced
384—Yard switching power purchased
385—Water for yard locomotives
386—Lubricants for yard locomotives
387—Other supplies for yard locomotives
388—Enginehouse expenses—yard
389—Yard supplies and expenses

(c) Station and Other Facilities (direct)
Account 373—Station employees
374—Weighing, inspection and demurrage bureaus
375—Coal and ore wharves
376—Station supplies and expenses

(d) Signals and Communications (direct)
Account 404—Signal and interlocker operation
405—Crossing protection
406—Drawbridge operation
407—Telegraph and telephone operation (overhead)

(e) Supervision and Miscellaneous (overhead)
Account 371—Superintendence
372—Dispatching trains
409—Express service
410—Stationery and printing
411—Other expenses
414—Insurance

(f) Casualties (overhead)
Account 415—Clearing works
416—Damage to property

417—Damage to livestock on right-of-way
420—Injuries to persons

(g) Loss and Damage (overhead)
Account 418—Loss and damage—freight
419—Loss and damage—baggage

(h) Joint Facilities (direct)
Account 390—Operating joint yards and terminals—Dr.
391—Operating joint yards and terminals—Cr.
412—Operating joint tracks and facilities—Dr.
413—Operating joint tracks and facilities—Cr.

(i) Accounts 403—Operating sleeping cars, and 408—Operating floating equipment may be analyzed separately.

As previously stated, train and locomotive operating expenses, with the exception of charges to Account 400, do fluctuate with movement. Freight and passenger business should be studied separately and averages of results per train-mile, locomotive-mile, car-mile, and net and gross ton-miles, should be examined, in order to arrive at the proper reason for fluctuating costs. Analysis of charges to Account 400 should be made by relating the number of engines handled to expenses (labor and material, separately). Analysis should also be made of the fluctuation in the ratio of train expenses to revenue.

The cost of train operation will be found in the following accounts:

Locomotive expense—Accounts 400, 392–399, inclusive
Train expense—Accounts 401, 402

These totals should be related by division, district or system to the train-miles, locomotive-miles and gross ton-miles, separately, for freight and passenger. Causes of fluctuations may be ascertained by a study of the unit costs of train operations and traffic statistics.

For the reason that the train and locomotive operating costs include the handling of all cars, loaded and empty, light locomotive movements, hauling of non-revenue freight, etc., the actual production of revenue ton-miles and passenger-miles is only part of the work performed, so that unit costs should be based on locomotive, train and gross ton-miles which do reflect all work performed.

For the control of overtime on way freights it is suggested that supervisory officers ride the trains for the purpose of establishing yardsticks. The reports of trips made should be set up in log form showing:

Time called
Time departed (explain initial terminal delay)
Time at stations enroute
By Stations:
Nature of work performed
Weight of LCL tonnage loaded and unloaded
Number of cars set out and picked up
Explanation of delays (occasioned by train crews or station force)
Time of arrival at terminal (explain final terminal delays)
Total hours paid for and amount of overtime

An analysis of these details should permit the establishment of work practices which will result in a reduction of the overtime. Analysis should be made of payments for dead heading, called and not used, etc.

The yard costs should be related to the number of cars switched, wages, and other yard cost statistics for larger stations.

Station costs do not necessarily fluctuate with traffic although platform costs should and while this cost is not set up separately in the accounts, most roads maintain tonnage handled at major points and wages of platform crews for the purpose of analysis. Other station expenses have a slight relation to revenue, and analysis should be made by comparison of forces in the periods being compared. Forces other than those engaged in platform work should also be checked by observations on the part of the superintendent, traveling auditors, transportation inspectors, etc., and also by relating costs to station earnings.

The expenses representing cost of injuries to persons, should, if excessive, be analyzed through the use of claim files for the purpose of ascertaining the action taken to prevent similar accidents in the future.

The other transportation accounts require special analysis and determination of satisfactory units as the expenses in these accounts are not necessarily related to traffic. However, the principle charge is for labor so that analysis of the force and rates should develop the reason for the fluctuation.

Dispatchers, signal and interlocker, and telegraph and telephone expenses may be satisfactorily related to transportation service train-hours including train switching hours.

Fuel analysis should revolve about the tons of fuel consumed, locomotive-miles, gross ton-miles and gross tons per train-mile, developing averages by various combinations to determine the cause of the fluctuation. Passenger fuel cost may be related to car-miles as well as gross ton-miles and fuel for switch engines related to switch engine-hours. If the cost of fuel is taken into consideration, the difference in price must be adjusted before effective comparisons can be made. Water expenses should be related to fuel consumption for analysis of fluctuation.

The index of the effort of the transportation department to reduce potential service over actual service is the increase in movement of revenue ton-miles or passenger-miles per train-mile.

Charges to Account 418 "Loss and damage—freight" may be analyzed by relating these expenses to revenues. Freight claims paid in one month are not necessarily related to the revenue of that month but are paid in connection with traffic that moved in preceding months. Any analysis of loss and damage charges should include a study of the efforts being made to reduce loss and damage and the effect thereof.

An analysis of insurance charges should include a study of changes in company program for insuring against losses.

5. *Miscellaneous Operations (Account VI).*—The operations accounted for in Accounts 441–445, inclusive, are usually subject to analysis through statements prepared in the accounting department, showing in detail how the expenses were incurred.

6. *Traffic (Account III) and General Expenses (Account VII).*—These expenses, Accounts 351–359, inclusive, and Accounts 451–462, inclusive, cover expenses for a relatively permanent organization that is not affected by minor fluctuations in business. A force analysis will generally disclose the reason for large fluctuations, although such an analysis will not disclose variations in cost of tariffs and tariff bureaus. In order to analyze these last two items it is necessary that a separation of the charges be made.

7. *Purchasing and Stores.*—The "stock record" is the basic record from which information can be obtained relative to the exact status of materials and supplies. In procuring, handling and distributing materials it is of prime importance that such a record be maintained. This record must disclose information as to the quantity of materials on

hand at a given date and also the quantity issued over a given period. The single item stock sheet facilitates the maintenance of these data.

The monthly report of stock on hand, received and issued, together with the usual calculation of days' supply on hand of each class of material discloses information necessary for control of material. These monthly reports are usually prepared by the main stores office, while a combined stock report is prepared for the entire railroad which furnishes the overall picture of the material accounts.

As far as the company is concerned, material in store stock is exactly the same as cash in the bank, and the accounting for and protection thereof should be conducted with the same care as if it were cash.

When ties and miscellaneous lumber are treated in the railroad's own plant, cost data are usually prepared in sufficient detail to permit analysis of the various items of expense.

Individual cost statements are usually prepared where any special operation, such as treating ties, is handled by the store department; such statements would include "cost of material," "handling and preparation of scrap" and "cost of reclamation."

Another valuable guide to the analyst is the average cost of handling materials and supplies. A monthly statement is usually prepared at main store points showing the value of the material handled, including labor charges for handling and the store cost per $1000 of material handled. This is an accepted measuring stick but where the figures are available, a cost per 100 lb. or ton of material handled would be better because there is no real relationship between the value of the material and the effort required to handle it.

8. *Stationery and Printing.*—There are stationery and printing accounts in each of the general account groups and in order to analyze these expenses it may be well to assemble all of these charges in one group. The plan of charging such material to the expense accounts should be disclosed on statistical statements, as in some instances the plan used will distort monthly charges and thus affect comparisons. An examination of the charges to these accounts should reveal the results obtained through the efforts of a printing committee as usually constituted on a railroad.

9. *Taxes and Rents.*—Railway tax accruals Account 532, Equipment rent accounts 503–507, inclusive, and 526–540, inclusive, Joint facility rents, accounts 508 and 541, must be compared in detail to ascertain reasons for fluctuation. Ad valorem taxes will remain fairly constant; in any event, the reports made by tax commissioners will usually explain increases or decreases in such charges.

10. *Cost Studies.*—Little has been said with regard to the routine or continuous cost studies that are made on many railroads with respect to certain items of expense; for example, the cost of operating passenger motor cars, the cost of repairs to individual locomotives, etc., because it is the general opinion these studies should not be on a continuous basis but should be made periodically as a check on the unit costs previously established.

B. Standard Costs—Costs in Terms of Units of Work Performed

In the sense used here, the cost of performing transportation service does not refer to the cost of hauling a particular commodity but to the cost of doing particular work such as laying rail, hauling trains, etc.

Standard costs are predetermined. They are the yardsticks used to measure the efficiency with which work is done, the standard representing the cost of labor and material that should be sufficient to do a particular piece of work. Such costs must necessarily be determined by units related to actual performance.

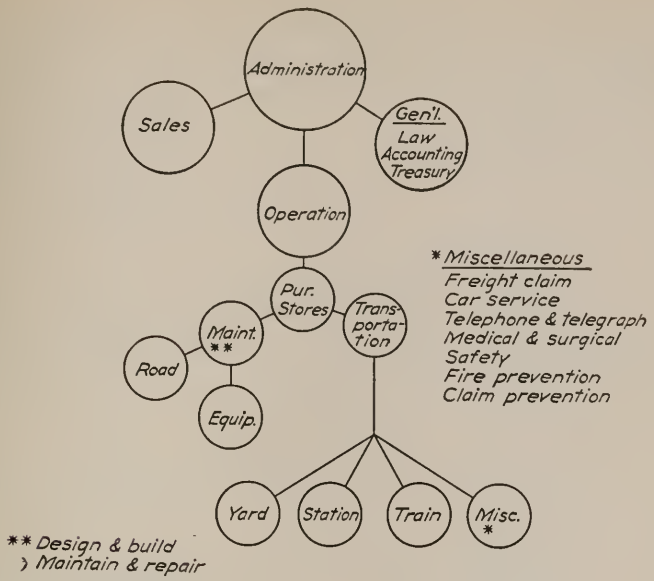

Exhibit A.—Chart of Functional Organization.

Exhibit A is a chart showing the functional organization of a railroad and the relationship of each function to the whole.

Exhibit B shows, by the basic functions, the component parts (operations) of each function. Opposite each component part is shown either the unit for which standard costs should be established or the unit that should be used to establish an average cost to measure efficiency.

Cost accounting is another medium for the enlightenment of management and it is necessary that it be utilized if the railroad properties are to be operated efficiently and economically. The aggregate costs used in developing unit costs under this system should agree with the books of account if the proper control of expenses is to be exercised.

Under most plans of cost accounting, numbered orders are issued for each piece of work and the direct labor and material used on the job are charged out to the job number. There seems to be no reason why some such system should not be followed, particularly in connection with maintenance work, and it is certain that the saving obtained thereby would be much more than sufficient to offset the cost of maintaining the records.

Costs may also be determined by what is known as the process method, that is, each class of work could be set up under a process number, and the costs of direct labor and direct material and overhead charged to that number during a given period.

So that the officers in charge of work may have the best statistical information possible to assist them in controlling their work, the report should not be based on the account distribution but should be set up so as to furnish costs on the basis of standards or units of work performed, which requires the following distribution of labor, material and miscellaneous charges.

EXHIBIT B

FUNCTIONS-BASIC	COMPONENT PARTS	SUGGESTED MEASURES OF EFFICIENCY
Administrative	President - Executive vice president, etc. Staff and expense	Relation to: (a) Gross revenue (b) Net revenue from railway operation (c) Net railway operating income (d) Net income
	Revenues	
Sales	Freight revenue - 101 Passenger revenues, 102, 103, 105, 108 Head end revenue, 106, 107, 109 Switching revenue - 110 Dining cars, hotels & restaurants - 131, 132 Station revenue - 133, 134, 135, 136, 137, 138, 139, 140	Commodity statements and ICC reports also Traffic expense per dollar of gross revenue, freight and passenger separately.
	Power - 141	Previous year's income
	Rent of buildings, etc. - 142	Previous year's income
	Miscellaneous - 143	Previous year's income
Traffic	Advertising	Relation to gross revenue
	Soliciting	Relation to gross revenue
	Preparation & distribution of tariffs	Relation to gross revenue (freight and passenger)
	Traffic associations	*Relation to gross revenue
	Fast freight lines	Relation to gross revenue
	Industrial & immigration bureaus	Relation to gross revenue
General	Accounting Law Treasury Staff and expenses	Relation to: (a) Gross revenue (b) Net revenue from railway operation (c) Net railway operating income (d) Net income
Operation		
Design.	Locomotives	AFE cost vs purchasing cost
	Cars	AFE cost vs purchasing cost
	Buildings	Contract bids
	Equipment (other than locomotives & cars)	AFE cost vs purchasing cost
	Road	AFE cost vs purchasing cost
Build	Locomotives	AFE cost vs purchasing cost
	Cars	AFE cost vs purchasing cost
	Buildings	Contract bids
	Equipment (other than locomotives & cars)	AFE cost vs purchasing cost
	Road	AFE cost vs purchasing cost

* Separate charges between tariffs and operating expenses

EXHIBIT M (cont'd.)

FUNCTIONS-BASIC	COMPONENT PARTS	SUGGESTED MEASURING OF EFFICIENCY
Maintain		
Road - Tracks	Surfacing	Linear ft. by ballast type & average per gross ton-mile
	Tightening bolts and spikes	Linear ft. or each
	Gauging	Linear ft. or number of ties
	Cleaning	
	cutting weeds, etc.	Linear ft.
	dressing ballast and cutting sod lines	Linear ft.
	removing snow, ice, sand	Linear ft.
	Patrolling and watching right-of-way	**Linear ft.
	plowing fireguards	Linear ft.
	Restoring rail, ties, ballast (Wrecks-washouts)	By wrecks and washouts and responsible department by mile posts.
	Taking up and relocating tracks	Chargeable to project
Structures	Painting	Area
	Watching (tunnels, subways, bridges, trestles and culverts)	Number of trains
	Grounds around buildings	Area
	Ventilating, lighting, (tunnels and subways)	Linear ft.
Repair		
Road - Tracks	Roadbed - fill	Yard cost
	Ties - track	Each
	Ties - switch	Linear ft.
	Rail	Each by feet
	Other track material	Linear ft.
	Ballast	Yards (cleaning), Placing - linear ft.
	Roadway machinery	Assigned track miles compare on basis of system track-miles
	Track tools	Linear ft.
	Roadway and track supplies	Linear ft.
	Bank protection	By mile post (by projects)
	Fences, snowsheds and signs	Ft. (fences, and snowsheds) signs - each project
	Public improvements	By mile post (by projects)
	Work train service	Linear ft.
	Joint facility, Dr. & Cr.	Each facility with related units
		Test bills vs division costs

** Regular program otherwise should be covered by special report.

EXHIBIT B (cont'd.)

FUNCTIONS-BASIC	COMPONENT PARTS	SUGGESTED MEASURES OF EFFICIENCY
Repair Structures	Buildings, fixtures, & appurtenances including pipe system - (drain water, gas, etc.)	By main building - small pooled - relate to value of building
	Bridges	Linear ft. by kind - pile, steel and concrete
	Trestles	Linear ft. by kind - pile, steel and concrete
	Culverts	Linear ft. by diameter grp.
	Tunnels and subways	Linear ft.
	Elevated structures	Each
	Wharves and docks	Each
	Power plants - (operation of trains and cars)	Each by valuation
	Power transmission system (electric, steam and compressed air)	Ft. in system
	Signals and interlockers (tower, buildings, fixtures, machinery)	Signals, linear ft. of track interlockers, each and group
	Telephone and telegraph) Outside plant)	Pole mile
	Terminal equipment	Each and group
Equipment	Shop machinery	Each
	Power plant machinery	Each
	Steam locomotives	Each
	Other locomotives	Each
	Freight train cars and small hand tools, included in MCB billing	(Repairs to system cars (and AAR Dr. (by groups of (cars) Foreign cars less (AAR Cr. (Poor inspection)
	Passenger train cars & small hand tools, included in MCB billing	(Same as above)
	Floating equipment	Each
	Work equipment - appurtenances and small tools	By class
	Miscellaneous equipment - wagons, automobiles, etc.	By class
Transportation Operation	Dispatching	Train miles
	Station employees including supplies and expenses	(Office - consignment (Freight house - tons
	Coal and ore wharves	Cars
	Operation - sleeping cars	Train miles in which operated
	Signals and interlockers	Train miles
	Crossing protection	Number of trains
	Drawbridge	Number of trains
	Telephone and telegraph	Wire miles
	Floating equipment	Miles of operation
	Express service	Car foot miles
	Other expenses	Train miles (special explanation)
	Operation-Joint yards and terminals) Cr. and Dr.)	Each facility with related units
	Operation-Joint tracks and facilities) Cr. and Dr.)	Test bills vs division costs

EXHIBIT B (cont'd.)

FUNCTIONS-BASIC	COMPONENT PARTS	SUGGESTED MEASURES OF EFFICIENCY
Yard	Yardmasters and clerks	Cars handled
	Yard conductors and brakemen	Cars handled
	Yard switch and signal tenders	Cars handled
	Yard enginemen and motormen	Cars handled
	Yard switch fuel	Cars handled
	Yard switch power produced and purchased	Cars handled
	Water for yard locomotives	Cars handled
	Lubricants for yard locomotives	Cars handled
	Other supplies for yard locomotives	Cars handled
	Engine house expense - yard	Cars handled
	Yard supplies and expenses	Cars handled
Train	Trainmen	Train miles
	Enginemen and motormen	Locomotive miles
	Fuel	Locomotive miles and gross ton-miles
	Power produced and purchased	Locomotive miles
	Water	Locomotive miles
	Lubricants	Locomotive miles
	Other supplies - locomotives	Locomotive miles
	Engine house expenses - road	Engines handled
	Train supplies and expenses	Train miles - car-miles
Miscellaneous Operations - Dining & Buffet Service - Hotels & Restaurants		
	Supervision	Dollars of revenue-dining car
	Commissary Employees	Dollars of revenue-material handled
	Stewards	Car Miles
	Cooks, waiters	Car miles
	Fuel and provisions	Meals served
	Laundry	Meals served
	Stationery and printing	Meals served
	Other expenses	Meals served
Grain Elevators Stockyards	Supervision Employees Fuel and Supplies	Special cost statement
Producing Power Sold	Stationery and Printing Other expenses	Special analysis
Other Miscellaneous Operations-Wood Preserving Plants		Cost per kind treated
General	Salary and expenses-general officers Salary and expenses-clerks and attendants General office supplies & expenses Law expenses Joint facility - dr. and cr.	Relation to: (a) Gross revenue (b) Net revenue from railway operation (c) Net railway operating income (d) Net income Each facility with related units

EXHIBIT B (cont'd.)

FUNCTIONS-BASIC	COMPONENT PARTS	SUGGESTED MEASURES OF EFFICIENCY
Clearing Accounts		
Shop Expense	General shop employees	Direct labor
	Power	
	Heating	
	Lighting	
	Switching	
	Shop supplies	
	Incidental expenses	
Material Store Expenses and Stationery Store Expenses	Purchasing and handling	Value of material
	Storing and distributing	
	Switching, etc.	
Power Plants & Transmission & Distribution Systems	Maintenance and operation	Each special report of costs
Gravel Pits & Quarries	Labor and train service utilized	Production
	Investment	
Report only to Responsible Officers and Superiors		
Operating and Mechanical Departments	Office force	Direct labor
	Depreciation	Direct labor
	Dismantling property	Direct labor
	Deferred maintenance	Special analysis
	Amortization	Special analysis
	Injuries to persons	Each
	Insurance	Special analysis
	Stationery and printing	Special analysis
	Equalization	Special analysis
	Other expenses	Special analysis
Transportation	Office force	Direct labor
	Injuries to persons	Each
	Stationery and printing	Separate by major items such as tariffs, etc.
	Wrecks	Each
	Loss & damage-freight & baggage	Each
	Damage to property	Each
	Damage to livestock	Each
	Insurance	Special analysis

EXHIBIT C

Rating Schedule For Track Work

In applying all schedules add ten percent for detention, unless a different rate is authorized for a section by the superintendent.

Maintenance of Way	Hours
APPLYING RAIL ANCHORS	
Schedule, per anchor (Vaughn)	0.041
Modified Fair	0.015
BALLAST CLEANING	
1. With forks	
Cribs only, per cubic foot	0.0747
Shoulders only per cubic foot	0.0463
Center ditch only per cubic foot	0.0662
2. Through turnouts (from point of switch to end of switch timbers)	
(No. 6	32.00
(No. 8	43.00
(No. 10	52.00
(No. 16	81.00
(No. 20	99.00
3. Through crossovers	
One crossover time taken as equal to two complete turnouts	
4. With screens	
Schedule per cubic foot	0.040
UNLOADING CINDERS	
Shovel cinders over sides of 60,000 lb. capacity wooden cinder pit car	
Schedule per car	10.75

Payroll.—After deducting the amount of payroll charged to AFE work and cost of work performed for others, the remainder of each roll should be set up by the smallest unit or department, that is, section, station, shop, enginehouse, etc. This gross cost should be reported by the classes of work with which the related units of work should be shown. Where practical, standards should be established for each unit and they should be related to the actual performance as reported.

Material and Supplies as Used.—These charges should be reported by the same units or departments as the labor costs, and the material used should be related to the labor units. The reports should show the cost per unit of work.

Miscellaneous Charges.—Any charges that cover payments made on contracts should be reported so as to show separately the labor and material and units of work performed, with the cost per units.

Miscellaneous Charges Covering Other than Contract Payments.—These charges should be reported in a manner that will clearly show their nature, and special items should be reported individually to the officer responsible for the charge.

Unit Cost System for Promoting Efficiency of Track Forces

What has been accomplished by one railroad in the establishment of "standard" costs, is illustrated in the following outline of the use of this method for controlling maintenance of way expenses.

This carrier has developed a complete unit cost system for measuring the cost of maintaining track. After being in use for a number of years, the method justified itself as it was demonstrated that every item of track work showed a marked increase in efficiency and a decided drop in the cost. The cost system also resulted in a more efficient utilization of roadway machinery, as studies from the cost records maintained, showed they were not in use more than 50 percent of the time. The problem of securing the greatest use of the investment in roadway machines is one that is constantly before the management and the unit cost system is an aid in securing information as to the use

EXHIBIT C (cont'd)

Operation	Time Distribution - Minutes Per Frog			
	4-Hole Bars		6-Hole Bars	
	Continuous	Others	Continuous	Others
RENEWING FROGS				
No. 1 Removing 4 pair bars	63	48	75	60
2 Drawing 34 spikes	25	25	25	25
3 Removing old frog	15	15	15	15
4 Driving 34 tie plugs	11	11	11	11
5 Adzing	11	11	11	11
6 Placing new frog	15	15	15	15
7 Replacing bars & full bolting	110	81	150	120
8 Full spiking	34	34	34	34
Foreman one tenth	28	24	34	29
Flagmen two tenths	56	48	68	58
	368	312	438	378
Schedule for 16½ ft. frog 2 flagmen, hours per frog	6.1	5.2	7.3	6.3
Schedule for 16½ ft. frog No flagmen, hours per frog	5.2	4.4	6.2	5.2

SURFACING

Schedule No. 2. Tamping out of face with raise of one to two inches (without preliminary fork or shovel tamping in stone ballast)

	STONE	GRAVEL	CINDERS
Cribs 3/4 full per linear foot of track	0.202	0.073	0.035
" 1/2 " " " " " "	0.190	0.071	0.032
" 1/4 " " " " " "	0.179	0.067	0.030

Through turnouts add 50 percent

Schedule No. 3. Tamping out of face with raise of two to four inches (with preliminary fork or shovel tamping in stone ballast.) This schedule includes both preliminary raise and final tamping in stone ballast.

EXHIBIT C (cont'd)

	STONE	GRAVEL OR CINDERS
Cribs 1/2 full, per linear foot track	0.202	0.071
Cribs 1/4 full, per linear foot track	0.191	0.067

Schedule No. 4. First raise of four to six inches when complete renewing ballast following stripping of track; when track is tamped with forks in stone and shovels in gravel or cinders, to be followed immediately by another raise and tamping.

	STONE	GRAVEL OR CINDERS
Per linear foot of track	0.072	0.060

Schedule No. 5. Second raise of four to six inches when completely renewing ballast where track is tamped with forks in stone and shovels in gravel or cinders, following stripping of track. This schedule is also to be applied if the raise is from four to six inches and is complete in one lift.

	STONE	GRAVEL OR CINDERS
Per linear foot of track	0.119	0.086

CROSS TIES - HANDLING

Loading

Distance carried to car	10 ft.	25 ft.	50 ft.	75 ft.	100 ft.
Schedule for box car per tie	0.101	0.112	0.126	0.142	0.153
gondola " "					
flat car " "	0.083	0.095	0.109	0.125	0.135

UNLOADING

Schedule Per Tie	Hours
Unloading and stringing out from box car moving and ties placed at right angles to track opposite spotted tie	0.037
Unloading from moving box car and throwing in clear	0.025
Unloading from moving flat car and throwing in clear	0.017
Unloading from box car standing without piling	0.028
Unloading from flat car standing without piling	0.020
Unloading from moving gondola and keeping in clear	0.033

PILING

Schedule Per Tie	
In standard storage piles	0.050
In pyramid, working piles	0.025

made of machines. The plan developed is based upon the measure of the proper utilization which the track foreman makes of his forces in performing the tasks assigned to them, due consideration being given to the tools provided.

At the outset, time studies were made, and a normal time fixed for what is designated as standard unit man-hours for the performance of given classes of work on the various divisions of the railroad. In determining these standards, consideration was given the relative labor requirements of the individual items of operation involved in the job and its needs adjusted to form a balanced organization necessary for efficient work.

EXHIBIT C (cont'd)

TRUCKING

TIE PLATES OR RAIL ANCHORS ON PUSH CAR LOADED ONE WAY AND RETURN WITH EMPTY TRUCK -

OPERATION NO.	OPERATION	TIME DISTRIBUTION - MINUTES TO TRUCK ONE LOAD OF 500 ONE MILE
1	Load on truck, 5 men, 5 minutes	25
2	Trucking, 5 men, 32 minutes	160
3	Distributing, 5 men, 5 minutes	25
4	Returning with truck, 5 men, 16 minutes	80
	Foreman, one-tenth above time	29
	Two flagmen	116
	TOTAL	435

Schedule 0.0145 hours per plate.

TIE PLATES OR RAIL ANCHORS ON HAND CAR LOADED ONE WAY AND RETURN WITH EMPTY HAND CAR -

OPERATION NO.	OPERATION	TIME DISTRIBUTION - MINUTES TO TRUCK ONE LOAD OF 100 ONE MILE
1	Load on hand car, 3 men, 1.5 minutes	4.5
2	Going to point of use, 3 men, 6 minutes	18.0
3	Distributing, 3 men, 1.5 minutes	4.5
4	Returning with hand car, 3 men, 6 minutes	18.0
	Foreman, 1 man, 6.6 minutes	6.6
	Two flagmen	30.0
	TOTAL	81.6

Schedule 0.0136 hours per plate.

Exhibit C shows the rating schedules for track work, illustrating sample pages from a complete schedule consisting of 14 pages.

A cost organization was set up under a cost engineer for the system, with assistant engineers on each district of track maintained, the road being divided into 34 districts on 9 operating divisions. Basically, the cost system rests upon the time book kept by the foreman which is necessary for payroll and accounting work. Each day during the progress of the work in addition to recording the time of employees, the foreman also records the classification of work and man-hours expended. A sample sheet from a time book is shown as Exhibit D.

The semimonthly statement is utilized by the assistant cost engineer as the foundation for his unit costs analysis. The information for each section is assembled monthly by districts and the cost engineer's office combines all districts into a summary for the entire period. The consolidated figures are published each month and cumulatively to date. At the end of the year, a summary is made covering the full 12 months operation.

The analysis of the data starts with the assistant cost engineer. The data as received from the foremen are reduced to the unit man-hours required for each type of work. Then a comparison is made between these actual unit man-hours and the standard unit man-hours to determine the relative efficiency of the performance. While definite schedules are set up for the standard units the assistant cost engineer has considerable leeway in

EXHIBIT D

-1-

SEMI-MONTHLY DISTRIBUTION OF TIME WORKED

Average Hourly Rate _____
(For Use of Accounting Dept.)

_____Half of _____194__

Description of Work Performed	M.W. Code No.	1 16	2 17	3 18	4 19	5 30 31 Total Hours
ROADWAY MAINTENANCE - Tracks in yards over which switching is performed by yard switching locomotives.						
Other than main or running tracks at stations						
Main line and running tracks						
TRACK LAYING AND SURFACING - Tracks in yards over which switching is performed by yard switching locomotives.						
Other than main or running tracks at stations						
Main line and running tracks						
SIGNALS & INTERLOCKERS - Repairs						
SMALL TOOLS & SUPPLIES - Repairs						
REMOVING ICE AND SNOW - Roadway & Tracks						
SIGNALS & INTERLOCKER OPERATION - Cleaning						

applying schedules and, in the ultimate analysis, the percentage depends upon his judgment. For instance, if a foreman is working at a point where interruptions caused by traffic run more than are figured in the basic schedules, the assistant cost engineer will increase the basic unit so that the foreman will not be penalized by conditions beyond his control. This primary analysis may be termed the local analysis of individual foremen by the assistant cost engineers.

Exhibit D–1 illustrates the redistribution of the time and work performed. In Exhibit D the foreman has shown his time for a particular day as 84 hours and in Exhibit E has shown the work performed on that day as shown in Exhibit D–1.

It is assumed that the assistant cost engineer is familiar with the physical condition of the track at the point where the work is done, that is, double-track stone ballast territory, cribs ¾ full. The average detention percentage for the section has been established at 7.1 percent.

EXHIBIT D (cont'd.)

-2-

SEMI-MONTHLY DISTRIBUTION OF TIME WORKED

Average Hourly Rate_____
(For Use of Acctg.Dept.)

_____Half of _____194__

DESCRIPTION OF WORK PERFORMED	Amount	Accounting Dept. Use Gen.	Prim.	Class	Yard
ROADWAY MAINTENANCE-Tracks in yards over which switching is performed by yard switching locomotives		1	202	5	
Other than main or running tracks at stations		1	202	1-07	
Main line and running tracks		1	202	5	
TRACK LAYING & SURFACING-Tracks in yards over which switching is performed by yard switching locomotives		1	220	5	
Other than main or running tracks at stations		1	220	1-07	
Main line and running tracks		1	220	5	
SIGNALS & INTERLOCKERS-Repairs		1	249	5	
SMALL TOOLS & SUPPLIES-Repairs		1	271	5	
REMOVING SNOW & ICE-Roadway and tracks		1	272	5	
SIGNALS & INTERLOCKER OPERATION-Cleaning		4	404	5	

From the foregoing it will be noted that the redistribution is based on established factual data, while the foreman's distribution is an estimate only.

The analysis of the cost data on a system basis is largely limited to special studies to determine the effectiveness of particular machines or methods of work. When a question as to the desirability of changing maintenance practices is presented, the figures covering the present methods are available and afford opportunity for more enlightened judgment on the proposed change. Exhibit F shows a monthly statement giving the figures reported on a system basis.

It should be understood that the cost system outlined is superimposed on the daily reports required for timekeeping and material accounting in both maintenance and additions and betterments work, and it is believed a better record results than would otherwise be available.

In an endeavor to secure greater utilization and check the efficiency of roadway machines, the assistant cost engineers also receive logs of the operations of all machines

EXHIBIT D-1

Item	Foreman's Distribution	Assistant Cost Engineer's Redistribution
30 ties (dug in)	44 Hrs.	1.23 Std.Hrs. x 30 = 37 Hrs. x 1.14 = 42 Hrs.
312 ft. track surfaced	24	0.064 " " x 312 = 20 " x 1.14 = 23 "
312 ft. track regaged	10	0.058 " " x 192 = 11 " x 1.14 = 13 "
Detention	6	6 "
	84 Hrs.	84 Hrs.

The factor 1.14 used by the assistant cost engineer was obtained by the following calculation:

Total of foreman's time distribution less detention = 78 hours
Total standard hours allowed in table for all items = 68 hours

Therefore, the production rate for all work is 68/78 or 87.2 percent and the ratio of actual time to standard time for each item is found to be 100/87.2 = 1.14

in service prepared by the operator. This information is abstracted monthly on a form shown on Exhibit G, by the assistant cost engineer on each district and forwarded to the system cost engineer. The information thus obtained is also utilized in gang organization planning and as supporting data to justify requests for purchase orders.

The assistant cost engineers required for the operation of this unit cost system are located on the divisions and in reality act as assistant supervisors of track. They work closely with the gang foreman, checking his entries of work performed to see that it is being properly recorded and make suggestions to increase the efficiency of the gang. The publication each month of the record made by the districts has stimulated a healthy competition among the foremen so that each tries to keep his gang or district among the top performers of the railroad. It has also been found that this position acts as a training ground for future supervisory officers and the record made by those starting in these positions, who continued in the company service, shows they have moved steadily forward in the operating and maintenance departments.

Equipment Repairs.—Although this company does not have standards for the cost or man-hours required to repair equipment, it does maintain a basis for checking the efficiency in terms of man-hours. Regarding classified repairs to locomotives and major repairs to other equipment, records are kept of the man-hours required to perform the operations. The man-hours actually employed in such repairs are compared with the average of the previous three years for the same kind of work to determine the increase or decrease in efficiency.

Budget

As has been previously stated, the aim of all railroad officers must be to produce transportation at the lowest possible cost. Another medium that is available to assist in this effort is the budget. Too often the cause of business failure can be attributed to inadequate expense control. Control through a budget procedure is the remedy that is suggested. A railroad with its complex organization also needs the coordinating influence of a budget if it is to be operated efficiently.

The advance planning and the preparation of the budget with the attendant follow-up or check to ascertain that actual expenses did not exceed anticipated outlay, furnishes the supervisory officers an insight into the actual operation and results obtained there-

EXHIBIT E

- 1 -

SEMI-MONTHLY DISTRIBUTION OF TIME WORKED-AUTHORIZED WORK

_____Half of_____194__

Average Hourly Rate____
(For Use of Acctg.Dept.)

DESCRIPTION OF WORK PERFORMED	AFE NO.	PROJ. NO.	1 16	2 17	3 18	4 19	14 29	16 30	31	Total Hours
TOTAL HOURS WORKED										
GRAND TOTAL HOURS WORKED										

Correct:

_____
Foreman

Approved:

_____
Supervisor

-2-

SEMI-MONTHLY DISTRIBUTION OF TIME WORKED-AUTHORIZED WORK

_____Half of_____194__

Average Hourly Rate____
(For Use of Acctg.Dept.)

DESCRIPTION OF WORK PERFORMED	AMOUNT	: : :	: : :	: : :	: : :	: : :	: : :
TOTAL HOURS WORKED							
GRAND TOTAL HOURS WORKED							

Correct:

_____
Foreman

Approved:

_____
Supervisor

from that cannot be otherwise procured. This analysis again permits the comparison of actual expenses with the costs estimated on the basis of what labor, material and other expenses should be sufficient to do the work.

When the preliminary investigation is made, prior to the establishment of the budget plan, certain truths about the nature of expenses will become apparent and thus furnish the supervising officers a better understanding of their work, which is to control expenses. Controlling expenses does not mean reduction of expenses through the medium of a reduction in force, in fact, one thing that will be learned under the budget plan of operating is how to control the available labor so that sudden changes in force will not be

EXHIBIT F

MAINTENANCE OF WAY DEPARTMENT-CONDENSED
MONTHLY REVIEW-UNIT COST OF TRACK WORK

Month DECEMBER 1940 System . District

Item	Unit	Current Month Number	Current Month Cost	Accumulative Total For 12 Mos. Number	Accumulative Total For 12 Mos. Cost	Accumulative Same 12 Mos. Last Year Number	Accumulative Same 12 Mos. Last Year Cost	Accumulative Percentage Standing 12 Mos. 1940	Accumulative Percentage Standing 12 Mos. 1939
Tie Renewals-Digging in	Ea.	26,893	0.552	251,694	0.540	223,355	0.543	96.1	96.4
" " -Raising track	"	16,385	0.288	88,725	0.292	87,886	0.303	96.0	96.2
" " -Side track	"	13,070	0.416	74,512	0.397	113,672	0.407	96.3	95.9
" " - Switch	L.Ft.	17,498	0.082	224,118	0.089	251,397	0.088	95.5	96.1
Rail " -New	"			1,680,135	0.076	1,279,581	0.074	99.7	104.8
" " -Repair	"	132,332	0.098	1,358,817	0.087	998,217	0.082	98.2	100.1
" " -Side track	"	28,993	0.099	303,630	0.083	431,122	0.073	97.1	99.2
Other Track Renewals-									
" " " Tie plates	Ea.	9,205	0.052	70,622	0.046	153,553	0.040	96.6	95.6
" " " Lag screws	"								
" " " Rail anchors	"	22,504	0.011	188,572	0.010	150,706	0.009	96.9	98.2
" " " Rail joints	"	337	0.392	7,786	0.440	11,663	0.396	96.3	97.5
" " " Frogs	"	84	5.33	743	6.06	724	6.01	96.3	96.3
" " " Switch points	"	54	2.95	559	3.13	303	3.48	96.9	97.3
" " " Guard rails	"	70	2.13	700	2.41	733	2.61	96.4	97.2
Ballast-Main Track-Stone	L.Ft.	76,236	0.127	2,273,375	0.120	2,409,633	0.102	95.1	95.8
" " " -Gravel	"	102,045	0.072	2,354,334	0.081	2,110,241	0.072	96.5	97.0
Ballast-Side Track	L.Ft.	41,638	0.084	285,287	0.068	296,692	0.066	95.1	94.7
" Cleaning	Cu.Yds.	13,396	0.596	255,878	0.431	183,601	0.561	95.5	95.8
Line and surface-Main track	L.Ft.	2,665,745	0.027	30,536,693	0.026	32,501,463	0.026	96.1	96.2
" " " -Side "	"	363,885	0.023	2,568,732	0.023	2,624,172	0.024	95.9	95.9
Respacing Ties	Ea.	65,917	0.033	478,154	0.035	615,513	0.044	96.7	96.7
Regeging Rails	No.ties	119,247	0.037	1,006,803	0.038	948,102	0.036	97.0	96.4
Tightening & replacing bolts	Ea.	324,517	0.011	3,012,149	0.009	2,877,967	0.009	96.0	96.2
Roadway-Banking	L.Ft.	215,372	0.046	2,337,570	0.046	1,751,746	0.045	96.1	96.0
Ditching	"	571,641	0.025	6,227,985	0.023	6,221,021	0.021	96.3	96.0
Cleaning	"	288,417	0.008	5,855,007	0.008	7,549,681	0.006	96.2	96.1
Cinder ballast	"	19,044	0.108	174,596	0.073	190,381	0.062	96.3	96.0
M. of W. Distributed time	Hrs.	543,854	82.5	7,121,790	86.0	6,972,994	87.7		
" " " Undistributed "	"	9,302	1.4	113,903	1.4	106,789	1.3		
Conducting Transpn.Miscel.	"	47,386	7.2	512,705	6.2	444,552	5.6		
Other Dept.Miscl.Time	"	58,706	8.9	536,440	6.4	425,596	5.4		
Total Time	"	659,248	100.0	8,284,838	100.0	7,950,331	100.0		

EXHIBIT G

MAINTENANCE OF WAY DEPARTMENT
Monthly Report of Roadway Machines

District_____
Month_____

_____
Asst.Cost Engineer

LINE NO.	1 TYPE OF MACHINE	2 NUMBER	3 ACTUAL HOURS USED	4 ACTUAL DAYS USED	5 GALS. GASOLINE	6 PTS. OIL	7 MISC. SUPPLIES IN MONEY	8 KIND OF WORK
1								
2								
3								
4								
5 to 26 incl.								

LINE NO.	9 MAN HOURS	10 UNIT USED	11	12	13	14	15	16
1 to 26 incl.								

EXHIBIT H

DIVISION REQUEST
ESTIMATED CHARGES TO FREIGHT CAR REPAIRS
MONTH OF _____

CLASS REPAIRS

SHOPS	CLASS 1 No. Cars	CLASS 1 Class of Car	CLASS 2 No. Cars	CLASS 2 Class of Car	TOTAL NUMBER CARS	AVERAGE NET COST	TOTAL NET COST
TOTAL							

LIGHT REPAIRS

REPAIRS	days at	per day	
INSPECTION	days at	per day	
INITIAL APPLICATION OF "AB" BRAKES		cars at	per car
INITIAL APPLICATION OF HEAVY DUTY DRAFT GEARS		cars at	per car
PAINTING		cars at	per car
AIR BRAKE CLEANING AND SPECIAL INSPECTION		cars at	per car
OTHER ITEMS			
TOTAL			
GRAND TOTAL			

APPROVED:

(Division Title)

No. of Hours Per Week
Working Days Per Month
Estimated Mileage

necessary. It is well known that such changes are not desirable from the standpoint of efficient operations. Some of the things that will be learned about operation and operating costs in any department that undertakes to work on a budget are:

1. All expenses are made up of two parts:
   (a) fixed
   (b) variable

   Expenses that appear to vary with units of work will not vary exactly with the increase or decrease in the units because of the amount of work that can be added before additional labor is needed or because a minimum force will be required as long as there is some work available.
2. The preparation of the budget estimate or goal will require the department head to scrutinize each phase of operation that requires labor and material.
3. Operation under a budget permits the department head to exercise a control over expenses as conditions change, that cannot otherwise be obtained. It is definitely a goad to lethargy.
4. Trained business judgment is not bypassed through the use of a budget procedure but it is in a better position to function because of the improved data that become available currently.

It must be recognized that an organization equipped to handle the details must be set up if this plan is to work satisfactorily. In most cases, companies that started a budget plan and then discontinued it and reverted to such controls as can be exercised by watching the cash drawer or some other gage, did so because they attempted to have officers, already burdened, add budgeting to their duties.

The budget department will necessarily obtain the original estimates of expenses from the heads of the several departments but the budget department itself should be set up to function along the following lines, and for the purpose of assisting the responsible officers in the management of the property.

Before actually starting the plan of operating under a budget, it will be necessary to formulate the budget policy of the company and fully acquaint all officers with the extent of their responsibility under the plan. The policy as finally promulgated must establish:

1. The time period the budget will cover.
2. How the budget may be adjusted as conditions warrant and the latitude allowed officers to exceed the budget if necessary in their judgment.
3. What officers shall prepare departmental estimates.
4. What officer will be final in approving the budget.
5. How the budget is to be enforced.

The reports necessary under such a plan will have to be arranged for in substitution for those in existence. Where a change is necessary, standards or estimated unit costs must be established and agreed upon and members of the supervisory staff must be educated in their meaning and use. The duties of the budget department will include the following, or at least the indirect supervision thereof if it is found desirable to have certain functions, such as preparation of statistics, carried out in other departments.

1. Procedure.—The instructions necessary for the preparation of the budget estimates should be prepared by the head of the budget department.
2. Estimates.—When the budget estimates are received they should be reviewed and thoroughly discussed with the officer who prepared the original estimate. A continuous study and analysis of requirements should be carried out under this function.

3. Statistics.—This work should comprise the establishment and review of standards and the analysis, if not the preparation, of statistics showing actual results.

4. Economics.—A continuing study of the economic trends should be carried on in the budget department so that all budget officers may be kept fully informed to enable them to give effect to these trends in their budget estimate.

5. Coordination.—Effort should be made to keep the several departments informed of activities in any one department that result in decreased costs.

Revenue Estimate

It will be found advantageous to budget capital expenditures as well as all operating expenses and to do so over a period of six months or a year, a means must be found to estimate the revenues of the company satisfactorily. This will involve an advance study of traffic so as to fix upon some recognized factor such as gross national product or some other business index which, experience shows, is a guide to the revenue trend of the company. It may be necessary to divide traffic into groups, by commodities, and as to originating, terminating and overhead business and secure reports of business prospects through shippers advisory boards and local business institutions in order to arrive at a reasonable estimate of revenue. However, the estimate of the revenue is the heart of the budget plan so the method to be employed in making this estimate warrants careful planning to the end that reasonably accurate results will be obtained.

Expense Estimates

The estimates for maintenance of way, maintenance of equipment, and traffic and general expenses, seemingly can be established and are not affected by less than drastic changes in business, but the transportation expenses, like the revenues, must be carefully controlled as they should react promptly to slight changes in traffic.

J. Slater, then connected with the New York, New Haven & Hartford, in an article on Budgeting Transportation Expenses, in the *Railway Age* in 1924, made certain observations that must be considered when setting up this part of the budget. He stated that the original budget estimate must necessarily be based on the estimate of revenue but that the transportation budget must be flexible so that it will increase or decrease as traffic movement increases or decreases; thus, the budget will automatically move with the change in traffic. His analysis of transportation expenses revealed that these expenses do not fluctuate directly with volume, but that some fluctuate with passenger and others with freight traffic. The first step to be taken is to determine which expenses are fixed and which are variable.

Mr. Slater's analysis developed the following separation:

Fixed:

Supervision
Dispatching
Employees at small stations
Station supplies and expenses
Small yard expenses
Yardmasters and clerks
Switch and signal tenders
Operators of towers, drawbridges and crossings

Variable:

Expense	Controlling Work Unit
Freight house labor	Tons handled
Large yards	Cars handled
Freight train expense	Gross ton-miles
Floating operations	Cars floated
Coal and ore wharves	Tons handled
Passenger train expenses	Passenger train-miles

As has been previously pointed out, these expenses do not vary directly with the change in the units so that a study must be carried on to determine the percentage relation of increase or decrease in expenses to the increase or decrease in volume.

The following is an outline of method actually used by one carrier to check and control the maintenance of equipment expenses through the use of a budget. This budget method has given successful results over a long period and it is believed it can be adapted to the use of any other railroad.

About the middle of the month, the division superintendents and main shop superintendent submit their estimates for equipment expenditures for the following month. These are submitted on forms shown in:

Exhibit H—Request for Freight Car Repairs
I—Request for Passenger Car Repairs
J—Request for other M of E Repairs

Locomotives.—Each operating division of the railroad is assigned its complement of motive power with which to perform the required transportation service. This normally would include a certain number of road freight and passenger locomotives, as well as the necessary switching locomotives. Each unit of equipment, therefore, has its own home terminal where its performance may be watched and where the necessary inspection, servicing, and light or running repairs are done in order to keep it in service. Servicing or light repairs are necessary at the end of each run, whereas class or general repairs are usually made at stated intervals after a certain specified mileage has been made which is termed its potential mileage. Inspection and general condition, however, govern whether a particular locomotive receives class repairs, whether it has completed its assigned mileage or not. Thus, use is the principal factor which determines the amount expended on locomotive repairs, both running and class.

Many statistical units of measurement have been suggested or attempted as a means of controlling and comparing expenditures for locomotive maintenance, but the consensus of mechanical officers is that the most practical unit of measurement is the locomotive-mile. All costs, therefore, would be determined on the overall basis of costs per locomotive-mile. The use of this unit of measurement permits a comparison of cost between locomotives of the same general design operating in the same kind of service and gives those responsible for proper locomotive performance in railroad operations, the truest picture of the economy and efficiency of their efforts.

Class Repairs.—Since class repairs are only made after the preassigned mileage is run, it is necessary that mileage statistics be maintained showing the mileage each locomotive makes. Each specified class of locomotives is, therefore, assigned a definite potential mileage which it may be expected to run between class repairs, and unless the miles run out are 80 percent of potential, the locomotive is ordered kept in service with running repairs, providing these repairs keep it in a safe

EXHIBIT I

DIVISION REQUEST
ESTIMATED CHARGES TO PASSENGER CAR POOL
CLASS REPAIRS

SHOPS	NO. OF CARS	CLASS OF CARS	AVG. NET COST	TOTAL NET COST
TOTAL				

LIGHT REPAIRS

REPAIRS	days at	per day
INSPECTION	days at	per day
OTHER ITEMS		
TOTAL		
GRAND TOTAL		
No. of Hours Per Week		APPROVED:
Working Days Per Month		
Estimated Mileage		Genl.Supt.Motive Power

EXHIBIT J

DIVISION REQUEST
ESTIMATE OF M. OF E. EXPENSES
MONTH OF_____194_

ACCOUNT		ESTIMATED CHARGES
301	Superintendence	
302	Shop Machinery	
304	Power plant mechinery	
304	Power sub-station apparatus	
311	Other locomotive repairs	
320	Motor equipment of cars - repairs	
323	Floating equipment - repairs	
326	Work equipment	
329	Miscellaneous equipment - repairs	
332	Injuries to persons	
333	Insurance	
334	Stationery and printing	
335	Other expenses	
	TOTAL	

Maint. Joint Equipment Terminals - Net Debit or Credit
Total of M. of E. Estimate

ESTIMATED LOCOMOTIVE MILEAGE

	REVENUE	NON REVENUE	TOTAL
Steam locomotives			
Other locomotives			

Number of locomotives recommended to be given classified repairs

EXHIBIT K

BUDGET

ACCOUNT 308 - STEAM LOCOMOTIVE REPAIRS

_____Division

1. Revenue steam locomotive miles
2. Average miles per class repair
3. Class repairs:
   - A. - Shop - number
   - B. average cost
   - C. total cost (3A x 3B)
   - D average cost per locomotive-mile (3C ÷ 1)

4. Running Repairs:
   - A. - Average cost per locomotive-mile
   - B. - Total cost (1 x 4A)

5. Grand total cost (3C plus 4B)
6. Total cost per locomotive-mile (5 ÷ 1)
7. Class repair cost percent of total cost (3C ÷ 5)
8. Running repair cost percent of total cost (4B ÷ 5)

EXHIBIT K-1

BUDGET

ACCOUNT 308 - STEAM LOCOMOTIVE REPAIRS

CLASS REPAIRS

Division	Steam Loco. Miles	Avg. Mi.Per Class Repair	Main Shops No. of Locos.	Main Shops Avg. Cost	Main Shops Total Cost	Divn. Shops No. of Locos.	Divn. Shops Avg. Cost	Divn. Shops Total Cost	Total No. of Locos.	Total Avg. Cost	Total Total Cost	Percent of Class to Total
Eastern												
Central												
Southern												
Western												
Total												

RUNNING REPAIRS

	Main Shop	Total Cost	Divn. Shops	Total Cost	Total	Percent of Running to Total
Eastern						
Central						
Southern						
Western						
Total						

REPAIR COST PER MILE - (CENTS)

	Total Cost of Repairs	Cost Per Mile: Class	Running	Total Repairs
Eastern				
Central				
Southern				
Western				
Total				

Note: If an increase in mileage is secured over the total estimated miles, shown above, the running repair portion of the budget may be increased in the amount of the additional miles multiplied by the budget running repair per mile; and vice versa, the running repair portion of the budget must be decreased on the same basis when mileage is less than the total estimated miles.

operating condition. To keep locomotives in condition to handle all traffic needs, it is essential that for all locomotives a ratio of 50 percent between potential mileage and run out mileage be maintained. This means that each month a certain number of locomotives must be scheduled for class repairs if this ratio is to be maintained.

Running Repairs.—Inspection, servicing, and light repairs are usually performed in the roundhouses at the completion of a locomotive run and these costs are directly proportionate to the miles run. Since these repairs consist chiefly of labor, it is relatively simple to estimate the cost.

Budget Procedure.—When the division requests showing estimates as to revenue steam locomotive miles and number of class repairs required, furnished on Exhibit J, are received, they are checked against statistics maintained in the office of the superintendent of motive power, due consideration being given to the power required to handle the traffic anticipated in the estimated gross revenues. The correctness of the estimated mileage and the number of repairs having been decided, the estimates are entered on a system summary sheet, Exhibit K, and the average cost per class repair for each division, as well as the running repair rate per mile for each division, is inserted.

These average costs reflect current labor and material costs and are revised as these latter costs fluctuate or as operating conditions change. The divisions are then informed of their work allotments on a form showing information indicated on Exhibit K–1.

As the superintendent of motive power is furnished a daily summary of the mileage made by all locomotives, by divisions, the information as to miles is readily available for check with the estimate for the month and on the fifteenth and twenty-third, summaries of costs are drawn off for comparison with the estimates. As running repairs are wholly on a mileage basis, the divisions are permitted to increase their expenses to the extent of the increased miles multiplied by the rate per mile, whereas, if the actual miles show a decrease under the estimate, a corresponding reduction in expenses is required.

The divisions are held strictly to account for expenditures in excess of the amount authorized for class repairs and any overruns of the budget must be explained. By this procedure, the control of the budget allotment is always in the hands of the operating management.

It will be noted from this budget method that it is not required that routine statistics be maintained for repairs to individual locomotives. However, there are occasions when it is desired to test individual performance of locomotives in a particular class as against those in another class. In these cases, costs are accumulated from job tickets and time cards in the shops. This class of statistics falls more in the category of special statistics and it is no longer considered economical to keep such statistics on a routine basis.

Freight Train Cars

The objective of the operating management is the keeping of the ratio of bad order cars to the total ownership at a predetermined figure, say, between 2.5 and 3 percent. To maintain this ratio, it is necessary to have a certain number of cars pass through the shops for class repairs each month. Light repairs consisting of inspection, servicing, and minor repairs are made at interchange points and these expenses vary with the number of cars handled at these points.

EXHIBIT L

FREIGHT CAR REPAIR ALLOTMENT

CLASS REPAIRS

	Class 1 & 2 Repairs			Heavy Duty Draft Gears			"AB" Brakes					
	No. of Cars	Avg. Per Car	Total	No. of Cars	Avg. Per Car	Total	No. of Cars	Avg. Per Car	Total	No. of Cars	Avg. Per Car	Total
Allotment												
Division Estimate												
Proposed Allotment												
Increase or Decrease												

	PAINTING			Air Brake Cleaning and Special Inspn.			Light Repairs			Inspection		
	No. of Cars	Avg. Per Car	Total	No. of Cars	Avg. Per Car	Total	No. of Days	Avg. Per Day	Total	No. of Days	Avg. Per Day	Total
Allotment												
Division Estimate												
Proposed Allotment												
Increase or Decrease												

	Misc.	Total	Budget	Explanation of Miscellaneous Column: Division Request	First Proposed	Remarks
Allotment						
Division Estimate						
Proposed Allotment						
Increase or Decrease						

SUPT. MOTIVE POWER

R. & E.

	AAR	Regular	"AB" Brakes	Misc.	Total C.M.P.
Allotment					
Division Estimate					
Proposed Allotment					
Increase or Decrease					

GRAND TOTAL REPAIRS

Allotment	
Division Estimate	
Proposed Allotment	
Increase or Decrease	

Class Repairs.—About the middle of the month, the division superintendents and main shop superintendent are requested to submit their estimates for freight train car repairs on a form shown in Exhibit H. This shows the cost per class repair and the total estimated cost of class repairs for each class of work and for the division.

Light Repairs.—Under this heading is shown the number of working days in the month, the cost of light repairs per day, and the total cost of light repairs; the number of cars to be given air brake inspection and test, the cost per car, and total cost. Under inspection is shown the number of calendar days in the month, inasmuch as this is a daily job, cost per day for inspection and total cost. Under other items are shown any special amounts required in excess of amounts specifically allotted.

EXHIBIT N

PASSENGER CAR REPAIRS

	CLASS REPAIRS		PASSENGER CARS		LIGHT REPAIRS			INSPECTION		
Class of Cars	No. of Cars	Avg. Per Car	Total	Total	No. of Days	Avg. Per Day	Total	No. of Days	Avg. Per Day	Total
Allotment										
Division Estimate										
Proposed Allotment										
Increase or Decrease										

	Misc.	Total	Budget	EXPLANATION OF MISC. COLUMN Division Request	Proposed
Allotment					
Division Estimate					
Proposed Allotment					
Increase or Decrease					

SUPT. OF MOTIVE POWER AND DINING CAR DEPT.

	AAR	R. & E.	MISC.	TOTAL CMP	DINING CAR
Allotment					
Division Estimate					
Proposed Allotment					
Increase or Decrease					

	Misc.	Total	Budget	EXPLANATION OF MISC. COLUMN Division Request	Proposed
Allotment					
Division Estimate					
Proposed Allotment					
Increase or Decrease					

MOTOR CAR BODIES

DIVISION _____

	CLASS REPAIRS			LIGHT REPS. & INSPN.			
	No. Cars	Avg. Per Car	Total	No. Days	Avg. Per Day	Total	Misc. Total
Allotment							
Division Estimate							
Proposed Allotment							
Increase or Decrease							

	DIVISION 1	DIVISION 2	DIVISION 3	DIVISION 4	GRAND TOTAL
Allotment					
Division Estimate					
Proposed Allotment					
Increase or Decrease					

EXHIBIT M

BUDGET ALLOTMENT - Freight Train Car Repairs

Division 194__

REPAIRS		ALLOTMENT
Class	See details below for required output	$
Light	Days © $ Avg. Net Cost Per Day	$
Inspection	Days © $ Avg. Net Cost Per Day	$
Miscellaneous		
TOTAL		

REQUIRED OUTPUT OF CLASSIFIED REPAIRS

Shop	Class or Kind of Car	Number of Cars Class I	Class II	Total

EXHIBIT O

BUDGET ALLOTMENT - Passenger Train Car Repairs

Division 194_

REPAIRS		ALLOTMENT
Class	See details below for required output	$
Light	Days © $ Avg.Net Cost Per Day	
Inspection	Days © $ Avg. Net Cost Per Day	
Miscellaneous		
Total Pool Repairs		
Gas Car Bodies		
TOTAL ALL Repairs		$

REQUIRED OUTPUT OF CLASSIFIED REPAIRS

Shop	Kinds of Cars	Number of Cars
Total Allotment Dining Car Department		

When the estimates are received in the office of the superintendent of motive power, the entire detail is abstracted on a system freight train car repair sheet, Exhibit L, showing a comparison with the budget allotments for the previous month. The class repair estimates are reviewed and either permitted to stand or changed by the superintendent of motive power after consultation with the operating department. When the budget is finally approved, the divisions are informed of their individual work allotments on a form shown as Exhibit M.

EXHIBIT P

M. OF E. EXPENSE BUDGET - MONTH OF _____ 194_ TOTAL SYSTEM

		194_ Actual	194_ Actual	194_ Divn.Req.	194_ Proposed
Gross Revenue					
Total Maintenance of Equipment Expenses					
Total locomotive miles					
Revenue steam locomotive miles					
M.E. Exps. rate per locomotive mile ¢					
Steam loco. repairs % gross rev.					
Rate per steam rev. loco. mile. ¢					
Superintendence	301				
Shop Mach. Repairs	302				
" " Retire.	306				
" " Depn.	303				
Power Plant Mach. - Reprs.	304				
" " - Rets.	306				
" " - Depn.	305				
Power SubSta.Appr.- Reprs.	306				
" " - Rets.	306				
" " - Depn.	305				
Other Loco. Repairs	311				
Motor Equip. of Cars Rep.	317				
Floeting Equip. - Reprs.	323				
Work Equipment - Reprs.	326				
Misc. Equipment - Reprs.	328				
Injuries to Persons	332				
Insurance	333				
Stationery & Printing	334				
Other Expenses	335				
Depreciation Equipt.	Depn.				
Retirements Equipt.	Rets.				
M.Jt.Equip. at Terms. Dr.	336				
Ditto Cr.	337				
TOTAL ABOVE ACCOUNTS					
Steam Loco. Repairs	308				
Freight Train Car Reprs.	314				
Pass. Train Car Reprs.	317				
TOTAL 308-314-317					
TOTAL M. OF E.					
% OF GROSS REVENUE					

	Work	194_ Actual	194_ Actual	194_ Budget	194_ Divn.Req.	194_ Proposed
Steam Locos. - Class Repairs	Revenue					
Freight Cars - Class Repairs						
Cast Steel Side Frames	Class Repairs - Budget Transpn. Yds. Transpn. Yds. not in Budget					
Passenger Cars Class Repairs	Partial Complete					
"AB" Brakes	Class Repairs Transportation					
TOTAL						

EXHIBIT Q

BUDGET - Maintenance of Equipment Expenses

Account		Eastern	Central	Southern	Western	TOTAL
301	Superintendence					
302	(Shop Mach.-Repairs					
305	(" " -Depn.					
306	(" " -Dismant.					
304	(Power Plant Mach.-Reprs.					
305	(" " " -Depr.					
306	(" " " -Dismant.					
304	(Power Substa.Appr.-Reprs.					
305	(" " " -Depr.					
306	(" " " -Dismant.					
311	(Other Locomotives - Reprs.					
317	Motor Equip. of Cars					
323	Floating Equip. - Reprs.					
326	Work Equip. - Reprs.					
328	Misc. Equip. - Reprs.					
332	Injuries to Persons					
333	Insurance					
334	Stationery & Printing					
335	Other Expenses					
331	Deprec. Equip.					
331½	Amort. of Emerg. Fac.					
329	Dismant. Ret. Equip.					
330	Retirements - Equip.					
336	M.Jt.Equip.at Terms. Dr.					
337	M.Jt.Equip.at Terms. Cr.					
	TOTAL ABOVE ACCOUNTS					
308	Steam Locomotive-Reprs.					
314	Freight Train Cars "					
317	Passenger Train Cars "					
	TOTAL ACCOUNTS 308-314-317					
	TOTAL M. OF E.					

Passenger Train Car Repairs.—The budget for this account is handled in the same manner as just described for freight train cars; the system budget sheet being marked Exhibit N, and the work allotment to the divisions being furnished on form marked Exhibit O.

Other M of E Accounts.—The divisions estimate the amounts for each primary account on Exhibit J, and explain any increase or decrease from the previous month's allotment in a detailed memorandum. These estimates are entered on a system sheet, Exhibit P, showing comparison with the previous month. Each estimate is reviewed carefully and either permitted to stand or is changed by the office of the superintendent of motive power to agree with what that office considers should be spent in the month, based on current conditions. Allotments are then reported to the division on a form marked Exhibit Q, which provides additional lines to show the allotments for steam locomotive repairs, freight train car repairs, and passenger car repairs, in order that a total maintenance of equipment allotment can be shown.

Depreciation and Retirements.—The divisions do not estimate any charges to the depreciation and retirement accounts, inasmuch as the depreciation charges are fixed and only fluctuate from month to month to reflect the changes in the

capital account due to installations or retirements. Retirements of equipment are authorized exclusively by the superintendent of motive power and the estimates are based on what is contemplated in the month.

When the maintenance of equipment budget has been finally approved, the authorized division budget is transmitted by letter of the respective division and main shop superintendents.

Daily Statistics for Division Operating Officers

The following is a list of reports and records which the American Association of Railroad Superintendents has considered necessary to the efficient operation of a division:

Records and Reports

Most of the reports shown below are made daily, although in some cases, monthly summaries are also made where the reports lend themselves to the preparation of such information.

1. *Passenger and Manifest Freight Performance Report.*—This report, usually available between 6:00 a.m. and 8:00 a.m. daily, shows previous 24-hour performance.
2. *Yard Situation Report.*—Usually available from 6:00 a.m. to 8:00 a.m. daily, showing summarized performance of various yards on the division for the last 24 hours.
3. *Car Report.*—These vary with the size of the division, show cars loaded, unloaded, and interchanged at individual stations with a summary for the division.
4. *Power and Crew Reports.*—These give a daily picture of locomotives and crews available, enroute and ordered.
5. *Company Fuel Situation.*—This report is made daily, shows the supply of fuel available, enroute, on hand and needed.
6. *Abstract of Freight Train Performance.*—These abstracts vary with the individual division, but items usually shown are train number or symbol, engine, conductor and engineer, initial and final destination, number of miles run, time reporting, time departing, time arrived, time relieved, time enroute, total elapsed time on duty until relieved, number of loads and empties, and tonnage in and out of terminal.
7. *Terminal Report of Detailed Delays to Freight Trains Dispatched and Received.*—This shows time of arrival, time of relief, number of loads and empties, number of switches and in the case of intermediate or initial terminals, time ordered, time made up, time engine available, time departed and details of delay.
8. *Terminal Report of Handling Locomotives.*—This report shows time of arrival of locomotive, time arrived at roundhouse, time spent in roundhouse, time available for service, time ordered and time of leaving the yard, with a daily summary of the total time consumed in each operation.
9. *Daily Overtime Reports.*—These are daily reports of overtime on through freight, local, road switch and transfer runs as well as yard assignment.
10. *Freight Station Performance (At Larger Stations Only).*—These show number of clerical positions, number of foremen, number of platform workers and similar details, along with the tonnage of local freight handled and are usually made daily.

Some of the reports enumerated above frequently show comparisons of appropriate figures with similar figures for the previous year so as to aid a proper comparison of conditions.

Miscellaneous Reports

Other reports furnished currently but not necessarily on a daily basis, depending on subject covered, are:

1. Train accidents, "break-in-two" and personal injury reports.
2. Signal test reports.
3. Work train reports.
4. Station traffic report.

Conclusion

Although the purpose of this report is to assist in the reduction of paper work, it must be recognized that important controls over the property are exercised by management through the medium of reports furnished it. The accounts, cost systems, standards, budgets and statistics are all means that must be used if a property is to be efficiently managed. Your committee has endeavored to point to the simplest ways and means for making use of these managerial utilities with the thought in mind that more elaborate procedures could be curtailed after proper analysis. Reports and statements cannot serve in lieu of direct checks and observations. They can merely supplement and guide the officer in his efforts to curtail expenses. Hence, the committee believes that reports should be and can be simplified to a point where they will furnish only the basic data necessary for such guidance.

To make the utmost use of the reports it is necessary that a group of coordinators, auditors, traveling accountants or supervisors, or whatever title may be given them, be assigned for the purpose of checking to see that the business practices and procedures in use on the property are universally applied so that all divisions and departments will have approximately the same efficiency ratio.

Your committee offers this report as an overall picture of railroad statistics. If the benefits hoped for, that is, savings in man-hours, are to be realized it is necessary that only such statistical information be requested as will furnish material aid in the efficient operation of a property.

Operating—Transportation Division

C. A. Knowles, assistant to vice-president, Chesapeake & Ohio Railway, Richmond, Va.

J. A. Lockard, supervisor of motive power expenditures, Pennsylvania Railroad, Philadelphia, Pa.

R. K. McClain, assistant vice-president, Southern Railway, Washington, D. C.

Purchases and Stores Division

O. A. Donagan, general storekeeper, Boston & Maine Railroad, Boston, Mass.

W. J. Farrell, executive vice-chairman, Purchases & Stores Division, AAR, Washington, D. C.

Accounting Division

J. P. McDonald, general statistician, Atchison, Topeka & Santa Fe Railway, Chicago.

B. H. Moore, assistant to vice-president, Finance, Accounting, Taxation & Valuation Department, AAR, Washington, D. C.

J. F. Blair, auditor of expenditures, Chicago, Burlington & Quincy Railroad, Chicago.

Report of Committee 1—Roadway and Ballast

W. C. Swartout, *Chairman,*
F. W. Alexander
H. S. Ashley
George Auer, Jr.
F. W. Biltz
T. A. Blair
L. H. Bond
A. E. Botts
Clifton Brannon
H. F. Brown
C. B. Bryant
G. H. Burnette
W. J. Cable
J. E. Chubb
L. B. Craig
B. H. Crossland
A. P. Crosley
L. J. Drumeller
H. L. Exley
J. M. Fair
J. A. Given
A. T. Goldbeck
Albert Haertlein
F. W. Hillman
H. H. Hopkins, Jr.
J. W. Hopkins
S. M. Jackson
L. H. Jentoft
H. G. Johnson
A. R. Jones
O. N. Lackey
L. R. Lamport
H. W. Legro
Paul McKay
G. W. Miller
W. S. Moore
G. L. Morrison
J. A. Noble
M. C. Patton
L. H. Roden, *Vice-Chairman,*
G. W. Payne
H. P. Pickering
J. M. Podmore
J. W. Poulter
C. S. Robinson
L. S. Rose
J. R. Scofield
R. G. Scott
F. H. Simpson
W. C. Sneed
H. M. Tremaine
C. D. Turley
W. J. Turner
Stanton Walker
C. S. Wicker
P. H. Winchester
Edward Wise, Jr.
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Physical properties of earth materials.

   No report.

2. Natural waterways: Prevention of erosion.

   No report.

3. Culverts:

   (a) Investigate the use and design of wood culverts.

   No report.

   (b) Specifications for asphalt coating and paving of corrugated iron culvert pipe, collaborating with Committee 29—Waterproofing.

   Final report, submitted for adoption..... page 319

4. Roadway drainage: Adherence to recommended practice.

   Progress report, presented as information..... page 320

5. Roadway protection:

   (a) Stabilization of roadbed: Report on methods used.

   Progress report, presented as information..... page 320

   First progress report of the investigation of methods of roadbed stabilization ..... page 324

   (b) Structural support; struts; piling.

   Progress report, presented as information..... page 354

AREA Bulletin 458, February 1946.

6. Tunnels: Report on recent tunnel construction and maintenance problems.

No report.

7. Fences:

(a) Corrosion-resisting fence wire, collaborating with appropriate subcommittees of Committee A–5 on Corrosion of Iron and Steel, ASTM.

No report.

(b) Investigate extent of use of concrete fence posts.

No report.

(c) Electric shock fences and their adaptability to railroad requirements.

No report.

8. Signs: Specifications and plans for telltales—overhead and side.

Final report, submitted for adoption..... page 358

9. Ballast specifications.

Progress report, presented as information..... page 358

10. (a) Ballast cleaning.

No report.

(b) Study the use of ballast for out of face surfacing to determine proper type and height of lift.

No report.

11. Ballast tests:

(a) Studies of test methods.

Progress report, presented as information..... page 361

(b) Studies of effect of tamping.

No report.

12. Special ballast:

(a) Investigate the use of asphalt in ballast.

No report.

(b) Use of grout in ballast.

No report.

13. Specifications for riprap.

No report.

14. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3–A—General Reclamation of the Purchases and Stores Division, AAR.

No report.

The Committee on Roadway and Ballast,
W. C. Swartout, *Chairman.*

Report on Assignment 3(b)

Specifications for Asphalt Coating and Paving of Corrugated Iron Culvert Pipe

Collaborating with Committee 29—Waterproofing

G. W. Miller (chairman, subcommittee), H. S. Ashley, C. B. Bryant, J. A. Noble, M. C. Patton, R. G. Scott, H. M. Tremaine, P. H. Winchester.

Subcommittee 3—Culverts, in 1945 submitted as information Specifications for Bituminous Coated Corrugated Metal Pipe and Arches, Proceedings, Vol. 46, pages 495–501, inclusive.

A few comments and suggestions have since been received by your committee and after further study it is now recommended that the material contained on pages 495 to 501 be adopted and published in the Manual with the following revisions:—

In Section 11—Adhesion Test, page 500, second paragraph—delete all of the text beginning with second sentence which starts: "At the end of the 45 min. . . . .". Insert in lieu thereof the following:

"At the end of the 45-min. aging period, remove the specimen from the aging bath and immediately place it in a 70-deg. F. water bath, and allow the specimen to cool for 20 min. Then remove the specimen from the 70-deg. bath and dry the bituminous surface either by blowing or wiping lightly with a paper towel or cloth. Remove one of the hot adhesion anchors from the oven and press it into the asphalt coating as far as possible. Again immerse the specimen in the water bath, with the adhesion anchor in place and allow to cool for 5 min. Remove the specimen from the water bath and cut around the edge of the anchor with a knife blade or a cork borer. Place the specimen immediately in the pulling apparatus and pull the anchor. Immediately after the first anchor has been pulled another adhesion anchor shall be applied to the specimen following the routine given above. After the anchor has cooled for five min. in the water bath, it is pulled and the procedure is repeated for the third test. The elapsed time for the three tests, including the initial 20 min. in the 70-deg. water bath, shall not be more than 45 min."

Third paragraph, page 500—okay as is.

Fourth paragraph, page 500—revise to read:

"After the anchors have been pulled, determine for each exposed area on the specimen the percentage of that area with the galvanized surface exposed. (Note: In some cases the coating may have been removed and a brown oily film remain on the metal. The area covered by this film shall be considered free of coating.) A ruled counter-glass will aid in making an accurate determination of the percentage of the galvanized surface exposed."

Page 501, first paragraph—delete.

Page 501, second paragraph—revise to read:

"For the pipe to be acceptable, not more than one of the six areas tested on the two samples shall show as much as 25 percent of the galvanized surface exposed."

Report on Assignment 4

Roadway Drainage: Adherence to Recommended Practice

Clifton Brannon (chairman, subcommittee), H. S. Ashley, G. H. Burnette, J. E. Chubb, L. B. Craig, H. L. Exley, H. G. Johnson, R. G. Scott, H. M. Tremaine.

A continued study indicates that engineering officers are aware of the increased importance of roadway drainage, in both construction and maintenance. Generally speaking, French or rock drains for the drainage of water pockets in existing roadbeds have not proved satisfactory. They are, together with other forms of subsurface drainage, being superseded by other methods of stabilizing roadbed, such as pole driving and the grouting method. However, the recommended practices for surface drainage are generally being followed and where subsurface drainage installations are made, as they are for some special cases, the recommended practices for such installations are closely followed. No changes in the Manual are suggested at this time.

Report on Assignment 5(a)

Stabilization of Roadbed; Report on Methods Used

G. W. Payne (chairman, subcommittee), T. A. Blair, L. H. Bond, H. F. Brown, H. H. Hopkins, Jr., M. C. Patton, J. W. Poulter, C. S. Robinson.

Since the last report on this assignment, considerably more experience has been gained in the technique of stabilization of roadbed by pressure grouting, some data on the cost of grouting and subsequent maintenance are available, more evidence has been accumulated as to the effectiveness of pressure grouting and many additional railroads have undertaken projects which should hasten the development of knowledge of this method. In the light of the record to date, smoother riding track has been obtained with remarkable savings in maintenance.

Two basic types of grout injection equipment continue to be used and each has its ardent advocates. The greatest number of railroads use pneumatic equipment but the greatest mileage of track has been grouted with hydraulic equipment, largely due to the fact that one large western railroad using such equipment generally does an out of face job of a number of miles in each project.

Most pneumatic equipment used to date has been built in the railroad's own shops although some jobs have been carried out with commercially built grouters. On the contrary, the hydraulic equipment has largely been commercially manufactured. The first cost of pneumatic equipment is relatively little as compared with the hydraulic equipment but in the final analysis the equipment charge against the job is dependent upon many factors and not upon the first cost alone. There are not now sufficient data available to the committee to comment upon the economy of one type of equipment as compared to the other.

Some think that with pneumatic equipment, penetration of the subgrade by the grout is facilitated by the air which tends to open passageways for the grout. Even a slight lifting of the track is not considered serious because with the passage of the first train the track goes back to its original position.

Advocates of hydraulic equipment feel that they have better control of the grout injections than with air pressure and that with the high steady pressure possible with hydraulic equipment the grout can be forced into very resistant subgrade material.

The manufacturer who has supplied most of the hydraulic grouting equipment furnishes all necessary accessories for the work. It is understood that a manufacturer of railroad work equipment and motor cars is developing a pneumatic grouter with mechanical agitation which will be on the market next year. This manufacturer will also furnish grout points and all other accessories. With these two manufacturers in the field, complete hydraulic or pneumatic outfits will be available from stock.

Associated with these two types of equipment are two fundamental schools of thought regarding roadbed grouting. Although there seems to be no obvious reason from experience to date why one type of equipment should be used by the proponents of one school of thought while the other type of equipment is used by those taking the opposite view of the best method of accomplishing the same result, namely, a stable track, it is nevertheless a fact. Those who use pneumatic equipment generally advocate the use of rich mixes of portland cement grout ranging from neat cement with just enough water to permit injection, up to mixes of one part cement to two parts of sand with 7 to 8 gal. of water per sack of cement. It is the theory of this group that sufficient cement should be injected into the subgrade to form a slab of considerable strength in order to distribute the load on the underlying soft material and to keep water from reaching the stratum of the subgrade. Purely from the standpoint of getting the grout under the track with the least difficulty, less segregation and line plugs result with rich mixes than with lean ones.

The users of hydraulic equipment have inclined to the use of quite lean mixes on the theory that the objective of grouting is simply to displace water from the voids in the subgrade material and to fill those voids with compacted fine sand or cement so they cannot again become filled with water. The lean mix advocates very definitely try to avoid forming a strong or rigid slab. While grouts as lean as 1:12 with 48 gal. of water per sack of cement have been used, more commonly the mix is about 1:6 with 20 to 24 gal. of water. In these lean mixes the cement acts primarily as a lubricant, with emulsified asphalt added to the leanest mixtures to increase lubrication. In at least one instance air entraining portland cement was used instead of normal portland cement in a relatively lean mix. The result was the elimination of segregation, a well lubricated mix and good penetration of the subgrade without the use of emulsified asphalt. Although this is an isolated case, it indicates that further study should be given to the use of air entraining cement in lean mixes, and it is quite possible that there would be some benefit in its use in rich mixes as well.

There is not yet sufficient experience to prove definitely which equipment is the more effective or which of the two schools of thought regarding mixes is the more sound. The final answer to these questions must await the accumulation of longer time service and maintenance records.

Grouting Technique

As the general procedure or technique for pressure grouting has been discussed to some extent in previous reports of this subcommittee and has been the subject of numerous articles listed in the bibliography at the end of this report, only certain special features will be mentioned here.

Originally air pressures of 70 to 100 psi. were frequently employed. It has since been demonstrated that lower pressures are definitely more effective. The higher pressures are

conducive to segregation of the grouting ingredients with the result that line plugs often occur. By reducing the pressure to around 40 psi. this trouble is largely eliminated, if the grout is of the right consistency and the sand is not too coarse. Very fluid grouts made with sand coarser than engine sand are conducive to segregation and line plugs. Air pressures around 40 psi. moreover seem to ease the grout through the subgrade with the result that more grout is taken than when higher pressures are used.

It was customary in early track grouting jobs to drive a spud bar or bull point to form a hole for the grout injection point. Under some roadbed conditions it is necessary to preform a hole for the grout pipe but it has been found advantageous to use an extra heavy pipe which can be driven through the ballast and subgrade material. There is less leakage of grout around the pipe and less possibility of blowing the grout pipe back out of the hole during grouting.

Grout pipes are generally driven at an angle of about 30 deg. to the vertical and are started about one foot outside the ends of the ties. This brings the tip of the pipe just slightly outside the rail at the usual depth of soft spots. It was found on a job in the southeast, where solid rock underlies the track about 2½ ft. below the bottom of the ties that little if any grout was being taken when the pipes were only slightly inclined. Trenches were then dug at every third crib perpendicular to the track and to the depth of about 2 ft. in order to permit driving the grout pipes horizontally. Driving was stopped when the tips were approximately under the near rail. With the pipes in this position grout was received after first injecting water. The track was effectively stabilized.

Cost of Grouting and Saving in Maintenance

Costs vary considerably, depending upon the length of track being grouted, depth and extent of water pockets, familiarity of the crew with the particular subgrade conditions encountered, crew organization, whether an out of face job or spot grouting is being done, and many other factors. The cost of doing isolated jobs is therefore not particularly indicative of average results. It is better to consider the costs obtained on a large number of projects which when averaged should be fairly representative of what may be expected by any railroad working several crews throughout a season.

One large railroad using pneumatic equipment, stabilized 197 scattered water pockets or soft spots, having a total length of about seven miles, during the four years 1941 to 1944, inclusive. This work was done at an average cost of just a little over $1.50 per track ft. The annual maintenance cost over this soft track before grouting was approximately $2.35 per track ft., and since grouting the cost of maintenance has been just over $0.18 per track ft. In other words, the annual saving in maintenance is $2.17 per track ft., which means a 145 percent annual return on the cost of doing the work.

The savings in maintenance on jobs done with lean grout and hydraulic equipment have not been as great, on the average, as on those done with pneumatic equipment and rich grout. This is largely due to the fact that more out of face jobs have been done with hydraulic equipment and consequently low maintenance spots are averaged with those requiring frequent maintenance at high cost, whereas the spot grouting jobs done with pneumatic equipment have all required a great deal of maintenance before grouting.

On the other hand the cost of grouting on a large western road which has stabilized about 200 miles of track with hydraulic equipment has averaged about $0.65 per track ft. The reduction in maintenance on this track has ranged from 30 to 82 percent.

It would appear that pressure grouting is an effective way to save maintenance funds, and since the cost of grouting runs as high as 80 percent labor charge, it is evident that it is a very good way to release labor for other work.

Service Record

The first job of roadbed grouting as reported in last year's progress report was done in the fall of 1936 on the Pennsylvania near North Point, Md. The job is now 9 years old. Other isolated jobs followed in 1938 to 1940 and several projects were completed in 1941. The youngest of these is now 4 years old. Almost without exception every location about which information has come to the attention of the committee continues to show very noticeably improved riding qualities and only the minimum of routine maintenance has been required. In a very few cases the performance of the track has indicated the desirability of regrouting, which has been done with improved results. In many cases it is reported that it has not been necessary to place a jack under the track since the grouting was originally done.

Service records should accumulate more rapidly in the future because 36 railroads in the United States and Canada representing 154,000 miles of track have done and are continuing to stabilize roadbed by pressure grouting. With the large number of projects being done, very definite cost, maintenance and performance records should be available in the near future.

The committee concludes that pressure grouting has important possibilities as a remedy for soft track, irrespective of the depth of cut or height of fill, compares favorably with other and older methods of stabilizing track where the usual soft track conditions obtain, and that the saving in maintenance cost more than warrants the first cost of doing the work regardless of the question of permanence.

Bibliography

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   Railway Engineering and Maintenance, November 1944, page 1016.
4. Santa Fe Stabilizes 106 Miles of Roadbed.
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5. Roadbed Grouting Slashes Maintenance of Soft Track on New York Central.
   Railway Engineering and Maintenance, May 1945, page 474.
6. Roadbed Grouting Pays Big Dividends.
   Railway Age, May 5, 1945, page 787.
7. Stabilization of Roadbed—Committee Report of Roadmasters and Maintenance of Way Association.
   Railway Engineering and Maintenance, October 1945, page 1022.
8. Pressure Grouting Water Pocket Stabilizes Pennsylvania Track at North Point, Maryland.
   Concrete for Railways, Vol. 3, No. 4, page 3.
9. Pennsylvania Grouts 5 Water Pockets by Pressure Method at Fort Wayne.
   Concrete for Railways, Vol. 3, No. 4, page 6.
10. Pressure Grouting One of Five Stabilization Methods in Cleveland Test.
    Concrete for Railways, Vol. 3, No. 4, page 7.
11. Pennsylvania Reports Year's Operation Over Pressure Grouted Water Pockets.
    Concrete for Railways, Vol. 4, No. 2, page 3.
12. C. & O. Pressure Grouts Slabs Under Tracks in Tunnels.
    Concrete for Railways, Vol. 5, No. 3, page 9.

13. Keep 'Em Rolling Over Roadbed Stabilized by Pressure Grouting.
Concrete for Railways, Vol. 6, No. 4, page 3.
14. Terminal Railroad Association of St. Louis Pressure Grouts Special Track Work.
Concrete for Railways, Vol. 7, No. 2, page 3.
15. Santa Fe Pressure Grouts 100 Miles of Track.
Concrete for Railways, Vol. 8, No. 1, page 3.
16. Burlington Cuts Maintenance by Pressure Grouting Track on Gumbo Fill.
Concrete for Railways, Vol. 8, No. 2, page 3.
17. Service Proves B.&O. Pressure Grouted Track is Stabilized and Maintenance Reduced.
Concrete for Railways, Vol. 9, No. 1, page 3.
18. Maintenance Cut by Pressure Grouting Track in Test on Southern Railway.
Concrete for Railways, Vol. 9, No. 1, page 8.

Following as Appendix A is a separate discussion and progress report of the investigation that is being conducted by the Engineering Division research organization with funds supplied by the AAR. There is much valuable information in the report not heretofore available to the committee. The necessity for further research is evident.

Appendix A

First Progress Report of the Investigation of Methods of Roadbed Stabilization

Introduction

This is the first progress report of an investigation begun in May 1945 to study roadbed stabilization. The investigation is a part of the research work of the Engineering Division, and is being done at the request of the AREA Committee on Roadway and Ballast.

Unstable roadbed conditions due to poor drainage, yielding soil or the development of water pockets have long been a source of abnormal maintenance cost at certain track locations. In the past, much attention has been directed to methods for correcting these conditions and stabilizing the roadbed, with varying degrees of success. These methods have included the installation of tile, rock, or corrugated pipe drains and, more recently, the driving of ties or poles along the side of the track just beyond the ends of the ties. Increasing weight and speed of trains, together with wartime traffic volume and scarcity of maintenance labor, have magnified the problem.

Because the track is already built, the number of effective measures that might be used is limited by considerations of economy. The recent development of a method of stabilization by the injection of cement grout into the roadbed has been received with general interest, because it appears to offer a practical means of stabilization without rebuilding or even appreciably disturbing the existing track. As a consequence, the initial phases of this investigation will deal with this aspect of stabilization. If advisable, consideration will be given later to other methods which seem to give promise of success.

In May 1945, an agreement for a cooperative investigation was made with the Engineering Experiment Station of the University of Illinois, and in July, A. C. Shipps was employed on the Engineering Division research staff as roadway engineer to conduct the field work of the investigation. The planning and conduct of the work, and much of the preparation of this report, represent the cooperative efforts of Dr. R. B. Peck of the university staff, G. M. Magee, research engineer of the Engineering Division research

staff, and Mr. Shipps. The sudden death of Mr. Shipps in November 1945 was a most unfortunate loss to the investigation. Much of the resulting burden of the detailed presentation of this report then fell upon Dr. T. H. Thornburn of the university staff, whose assistance at a critical time was very helpful.

Considerable thought was given to the method of conducting the investigation. It was decided to make detailed observations of grouting work at selected locations on several railroads using different techniques of grouting, to make exploratory trenches for determining the distribution of the grout, to ascertain the essential properties of the soil, to make detailed records of the methods used, and to observe the service performance of the grouted track until sufficient data are obtained to permit the formulation of conclusions and recommendations for the most effective use of the grouting procedure.

In the following pages, such information is given with regard to grouting operations on five different railroads. Although it is too early to present any conclusions, it is believed that the information may be of immediate interest as representing a survey of current practices.

Essential Features of Grouting Procedure

Although grouting procedures on each of the five railroads discussed in this report differed in many respects, they all had certain features in common. Therefore as an introduction to the detailed studies, the following summary of the essential elements is presented.

On every grouting job, a mixture of cement and water, usually combined with sand and possibly other admixtures, is agitated until it forms a slurry. The slurry is then forced under pressure into a hose line which terminates in an injection point or grout pipe driven into the ballast or subgrade. The slurry emerges from holes in the lower part of the grout pipe and flows into the roadbed. The injection is continued until it is deemed that sufficient grout has been forced in, or until the grout breaks to the surface or begins to raise the track. At this stage, the hose line is disconnected from the grout pipe, the pipe is removed, and the injection is continued at another location.

To carry out these operations, it is necessary to provide a mixer, a machine for applying pressure to the slurry, hose lines, injection points, air hammers to drive the points, an air compressor, and miscellaneous small equipment. The mixer and the grout pump are commonly combined into a single machine.

At the present time, two types of grouting machines are in general use. In one, a displacement pump is used to force the grout into the lines; in the other, compressed air is employed. Displacement-type machines have been constructed by some railroads in their own shops. Commercial equipment is also available. Pneumatic equipment has been built by several railroads. It is also available commercially from a number of concerns.

Since a knowledge of the details of the grouting equipment is not essential to an understanding of the process, the commercial machines will not be described in this report. Such information can be obtained readily from the manufacturers. The principal characteristics of company-built machines will be mentioned in the descriptions of procedures on the various railroads.

The grout hose is commonly 1¼ in. in diameter with standard trainline connections for ease in coupling and uncoupling. Standard 1¼-in. pipe and fittings are used on some jobs, but a flexible arrangement has proved more efficient.

Some injection points consist merely of a length of double-strength iron pipe about 1¼ in. in diameter. The pipe is usually driven with a loose plug or bolt in the lower

end until the desired depth is reached, whereupon the plug is rodded out before the hose is connected. Special grout points of more rugged construction are available commercially. For example, the point manufactured by the Koehring Company, Milwaukee, Wis., is an alloy steel pipe with a solid hardened tip. The grout emerges from two ½-in. diameter holes located in the wall of the pipe at a distance of 6 in. above the tip. If the points cannot be driven through dense ballast without breakage, solid steel "hard points" are used to form a hole before the grout points are driven.

Ordinarily, a 52-lb. air hammer is used to drive the injection points. If hard points must be driven, a 72-lb. hammer may be required. The air is generally furnished at a pressure of about 90 lb. per sq. in. by a compressor having a capacity of 65 to 210 cu. ft. per min. If pneumatic methods are used to pump the grout, the same compressor may be used for both operations.

The following detailed reports describe grouting operations on five railroads. On three of these, the Chicago, Rock Island & Pacific, the Missouri–Kansas–Texas and the Atchison, Topeka & Santa Fe, the grouting machines were of the displacement type. On the other two, the New York Central and the Chicago, Milwaukee, St. Paul & Pacific, they were pneumatic. On the M–K–T and the Santa Fe the roadbed was of old construction and ballasted rather deeply; on the Rock Island the roadbed was newly constructed and the ballast section was not as deep. On the New York Central the ballast section was relatively deep and free draining, whereas on the Milwaukee it was somewhat shallower and relatively tight. Therefore, the five reports cover a wide variety of conditions.

Chicago, Rock Island & Pacific, Mercer, Mo. to Princeton

General

The track stabilization work described in this report extends from M.P. 382, just north of Mercer, Mo., to M.P. 397, south of Princeton, Mo., a distance of 15 miles. Throughout this distance, the railroad is a single-track line which was constructed in 1942.

North of Princeton (M.P. 392), the line traverses a region covered by a thick deposit of glacial till consisting largely of clay with many small boulders and pebbles. South of Princeton, the soil is derived from the underlying limestone, sandstone and shale bedrock of Pennsylvanian age. In both regions, the soil borrowed for fill is a heavy clay. Values of characteristic physical properties of typical samples are given in the following table:

	Glacial Region			*Bedrock Region*			
M.P.	397.8	391.27	382.37	397.2	397.8	397.10	397.10
Liquid limit, percent	56.8	38.8	75.8	44.0	56.8	46.5	57.5
Plastic limit, percent	26.0	14.0	26.3	16.3	26.0	16.7	22.3
Water content, percent	31.2		36.6	18.0	31.2	27.4	25.8

(Note.—For definitions of terms, see Table 1, page 334.)

These values indicate that the clay is highly plastic, and that there is no essential difference in the subgrade materials found in the two regions.

The line contains several deep cuts and high fills. The fills were built in layers, each well compacted by sheepsfoot rollers. After the subgrade was brought to grade by cutting or filling, a 10-in. layer of subballast was placed. The subballast, known as red-dog, consists of the residue after spontaneous combustion of dumps of shale and impure coal wasted from coal mining operations. It has the appearance of a red shale. Above the subballast was placed a 5-in. layer of ballast consisting of well-graded chats having a maximum size of ¾ in. The chats are a hard, durable product obtained by crushing waste from lead and zinc mines in Missouri.

Under the action of traffic, there has been some settlement, especially during wet weather. The settlement of the track is accompanied by a lateral squeeze of the subballast and the upper few inches of the subgrade. The extruded material appears along the ends of the ties in the form of a ridge which must occasionally be removed. As additional ballast is tamped beneath the ties, ballast pockets develop near the ends of the ties. Water becomes trapped in these pockets, inasmuch as both the subballast and the subgrade are relatively impervious. The water softens the shale and the upper part of the clay, and accelerates the squeezing process.

Grouting Procedure

Grouting is done by means of a Koehring heavy duty mud jack. The grout is injected through Koehring injection points driven to the working depth by a 72-lb. jack hammer. Air for the hammer is furnished by a Chicago Pneumatic compressor rated at 105 cu. ft. per min. Grout is delivered to the point through a single line consisting of two 200-ft. lengths of 1¼-in. flexible hose, coupled together. Work progresses toward the grouting machine from a starting point 400 ft. away.

Initially, a six-foot point was used. It was driven about five feet into the ground, so that grout was injected about three feet below the top of the clay subgrade. The points were located as shown in Fig. 1. In August 1945, a point four feet long was adopted in the belief that a larger quantity of grout could be injected per track foot. The grout emerged from this point near the contact between the subgrade and the bottom of the subballast. At the same time, the location of the points was changed to that shown in Fig. 2. Because of the shallow ballast, the points were driven into the soil directly, without the prior formation of a hole by means of solid steel points.

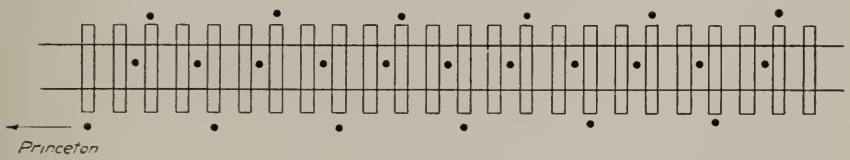


Fig. 1.—Spacing of Grout Holes, Original Plan—M.P. 397 to M.P. 393—1:6 Mix—Oklahoma Sand.

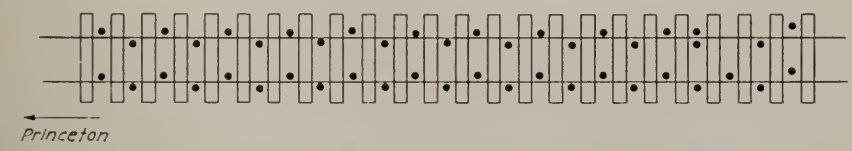


Fig. 2.—Spacing of Grout Holes, M.P. 392 for Tangent Track—1:6 Mix—Kaw River Sand. Outside Holes on Upper Part of Superelevation Omitted on Curves.

The grouting slurry consisted of 1 bag of portland cement, 6 cu. ft. of sand, and 28 gal. of water. The original grouting as well as the second grouting near M.P. 397 was done with a slurry containing an angular, somewhat coarse sand from Oklahoma. The rest of the line was grouted with a slurry containing fine sand from the Kaw River near Topeka, Kans. The grain-size characteristics of these sands are shown in Fig. 3.

On the average, 45 sacks of cement were used in an 8-hr. day. From 0.95 to 1.5 cu. ft. of grout per track foot were injected.

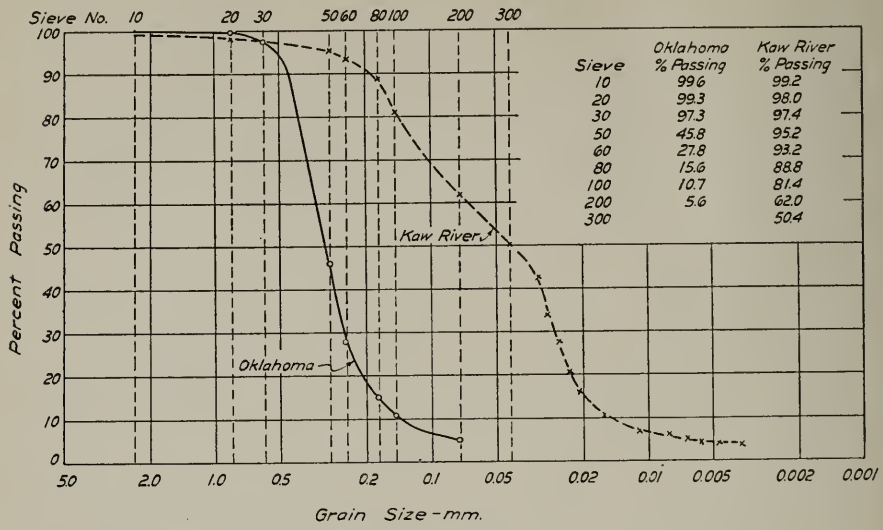


Fig. 3.—Rock Island Railroad, Mechanical Analysis of Grouting Sands.

Results

Results of the grouting were investigated by inspection of some 25 trenches cut through the ballast and subballast at various locations. Some of the trenches were dug before grouting, in order to determine the shape of the ballast pockets, the moisture conditions, and the consistency of the subgrade. The conditions are shown by the sketches in Fig. 4. In some trenches, the red-dog subballast was found to be very wet. In others, it was impervious enough to trap water within the chat ballast. The clay subgrade was soft to a depth of about six inches below the subballast. At a depth of about a foot, the clay became very stiff.

Three trenches were dug between M.P. 391.0 and M.P. 391.8 in a fill section about 15 ft. high, where no excessive maintenance has been required. No ballast pockets were found in these trenches, but in one of them (M.P. 391.8) the subgrade material was beginning to work into the ballast.

Examination of trenches excavated after grouting indicated that, in general, the grout occurred as streaks or lenses in the subgrade or subballast. In many instances, the lenses followed the contact between the subballast and subgrade, and broke through the subballast onto the shoulder. The lenses seldom extended for more than a few feet, and did not form continuous sheets across the subgrade. Typical results are shown in Fig. 5.

In only one instance was the ballast penetrated by grout. This occurred where the four-foot grout points were driven at a very flat angle from the ends of a tie in an effort to penetrate the shallow ballast pocket. The results of this experiment are indicated in Fig. 6.

To make sure that grout entered the porous material, two additional holes were drilled in the grout points, respectively three and seven inches above the uppermost original holes. Furthermore, the speed of the grout pump was reduced to decrease the

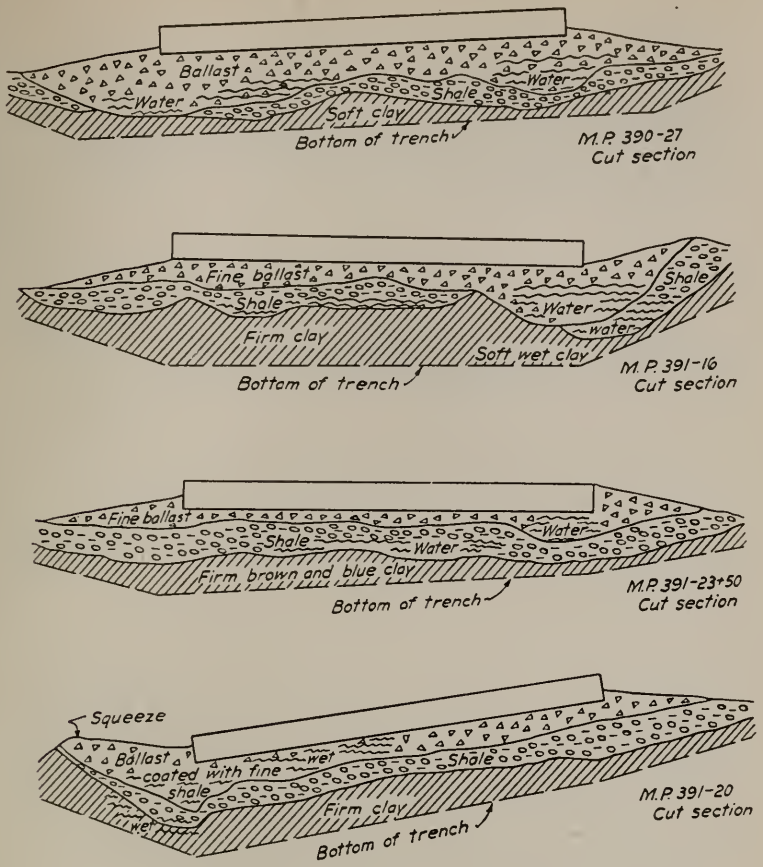


Fig. 4.—Rock Island at Princeton, Mo., Condition of Subgrade Before Grouting.

grout pressure. These changes resulted in better penetration of the ballast section, as indicated in Figs. 7a to 7c, and apparently a more continuous layer of grout across the top of the subgrade. The ballast section was not always penetrated, as shown by Fig. 7d.

The 1300 ft. near M.P. 397 was grouted twice. The subgrade was said to be soft at the time of the first grouting operations. After 30 days of traffic, the subgrade started squeezing from beneath the ties toward the shoulders, and carried seams of the grout with it. The grout was displaced from the region directly beneath the rails. Several fragments were examined which appeared to be broken from a sheet about 1½ in. thick. The other grouted sections have required little or no maintenance up to the present time.

Comments on Procedure

To study the effect of the grouting technique on the penetration obtained, three test sections were established near M.P. 383. One section was grouted using the grout point spacing and the procedure developed during the summer of 1945, and the standard

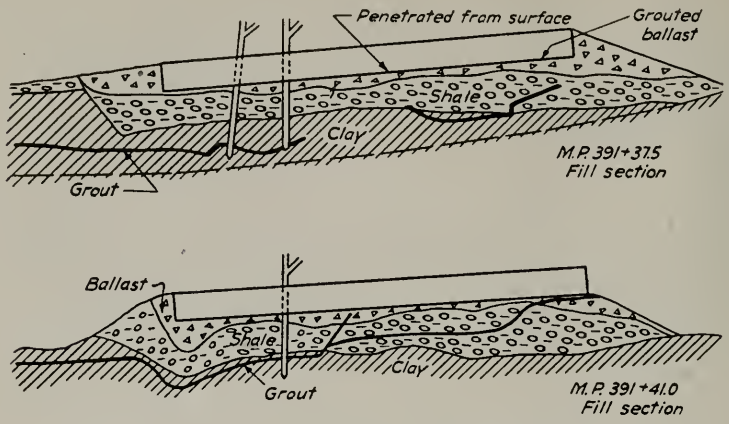
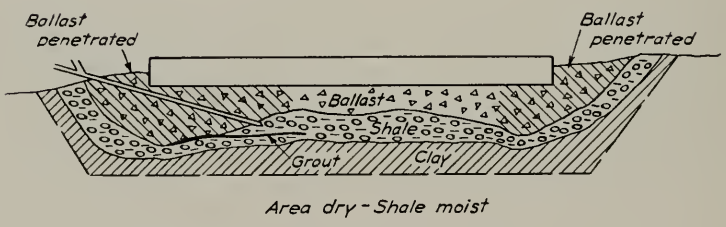


Fig. 5.—Rock Island at Princeton, Mo., Results of Grouting by Initial Procedure.



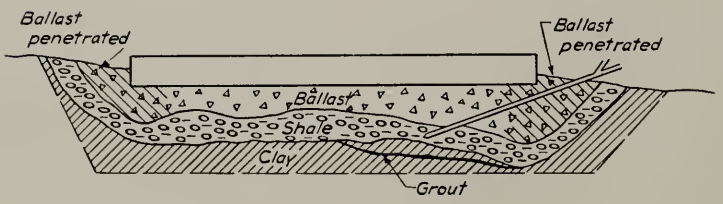


Fig. 6.—Rock Island at Princeton, Mo., Results of Grouting by Means of Grout Pipes With Very Flat Inclination.

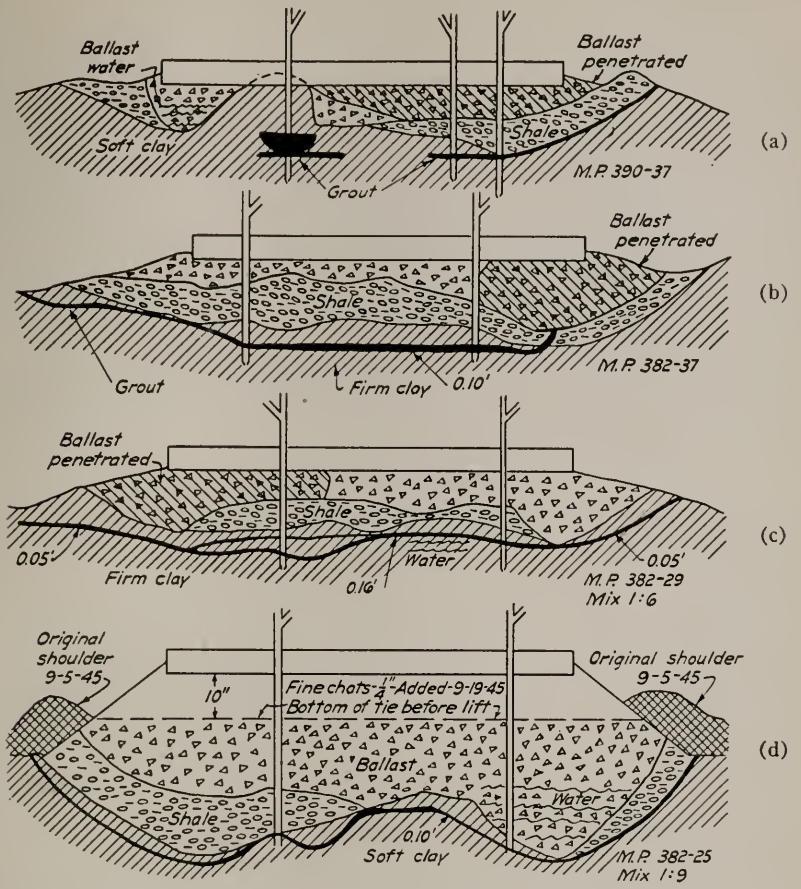


Fig. 7.—Rock Island at Princeton, Mo., Results of Grouting After Adding Holes About One Foot Above Grout Point.

grout mix of 1:9. In a second section, in which the mix was 1:6, the same grout point spacing was used, but the grout injection was preceded by a compressed air blast. In the third section, a 1:6 mix was also used, and the grout points were spaced as in the preceding sections. In addition, grout points were driven at a flat angle beneath the ends of each tie. A fourth section at M.P. 391 + 22 was grouted with a 1:12 mix, using the standard spacing of grout points. These sections have been completed, and are being examined by trenching. The results will be available at a later date.

Organization

This year's grouting was done under the supervision of one foreman. One machine operator, his helper and three laborers handled mixing operations. A grouting crew of four men handled the job of spotting the holes, driving and removing the points, injecting the grout, and plugging the grouted holes.

The mud-jack is set on standard track wheels and can be moved from one location to another by a track motor car. All of the auxiliary equipment can be loaded on a push car and moved at the same time.

Missouri–Kansas–Texas Near Savonburg, Kans.

General

The grouting described in this report was done under contract by the Better Welding Company of Ft. Worth, Tex. to stabilize soft sections of track from M.P. 103 to M.P. 113, between Moran and Savonburg, Kans. The railroad consists of a single-track line winding through an undulating to gently rolling terrain requiring medium cuts and fills seldom exceeding 10 ft. in depth. In some of the cuts, outcrops of limestone and shale are exposed.

The soil is black to brown residual clay of medium plasticity, developed on deposits of the upper Pennsylvanian age. The liquid limit of a representative sample was 58.0 percent and the plastic limit 24.8 percent.

A well compacted surface ballast of fine chats about 1½ ft. thick is underlain by about 6 in. of cinders which rest on the brown clay subgrade. Ballast pockets 2½ to 3 ft. deep have developed under the ends of the ties. They generally contain water, particularly in the cut sections.

Grouting Procedure

The machine used on this job was designed and built by the Better Welding Company. It was a self-contained unit with two mixers so mounted as to furnish grout to a single displacement-type pump, which developed a pressure at about 75 to 135 lb. per sq. in. One skip loaded material into both mixers. A compressor with a capacity of 210 cu. ft. per min. was used to furnish air for the 72-lb. jack-hammer used to drive the grout points. The 1½-in. grout line from the machine was connected through a 3-way valve to two 250-ft. lengths of 1¼-in. high-pressure grout hose. With this arrangement, it was possible to grout through only one pipe at a time, but grouting was an almost continuous process as only a turn of the valve was required to change from one pipe to the next after the hose connections were made. The grout pipes were designed by the Better Welding Company. They were driven to a depth of 4 ft. and at such an inclination that their tips were directly below a point about midway between the rail and the end of the tie.

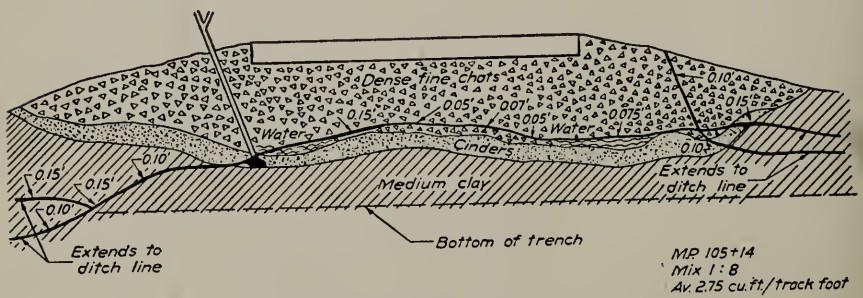


Fig. 8.—M–K–T Near Savonburg, Kans., Results of Grouting.

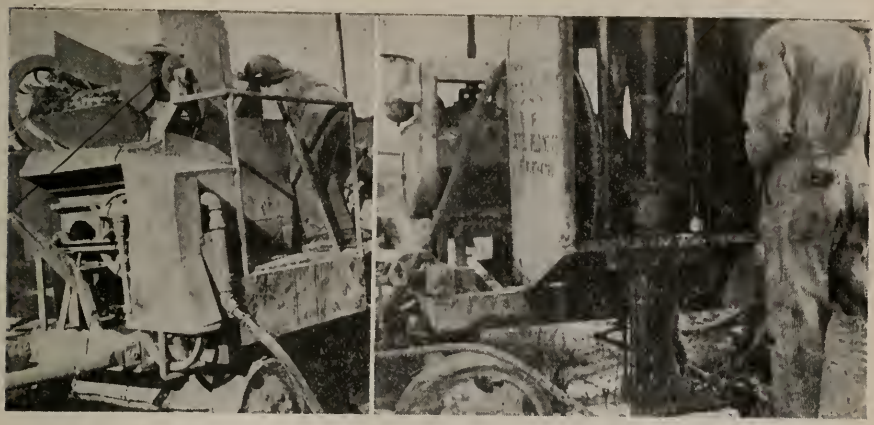


Fig. 9.—Views of Grouting Equipment Used on M–K–T at Savonburg, Kans.

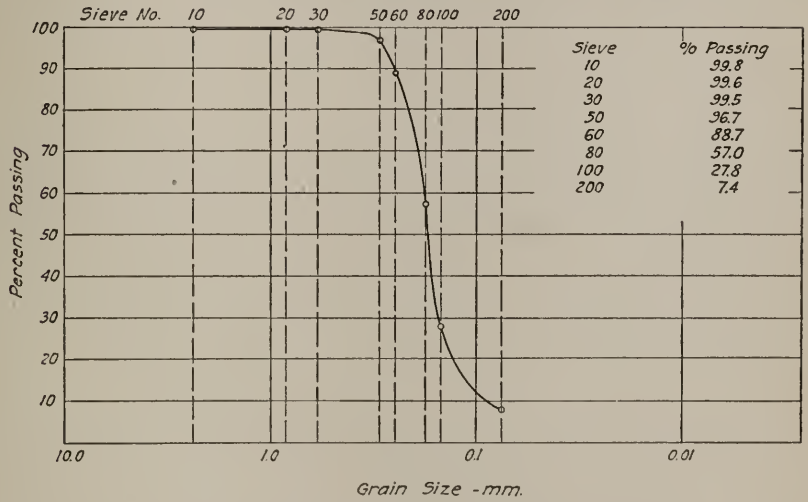


Fig. 10.—Mechanical Analysis of Grouting Sand—M–K–T.

Grout was injected at every fourth tie along one side of the track and then at the same ties along the other side. Additional points were then driven and grout injected at locations midway between the holes of the first set. Thus, grout was actually injected at every other tie on both sides of the track. In the event that a certain area of track took an unusually large amount of grout, additional points were driven along the edge of the ballast line on both sides of the track, usually at a spacing corresponding to every fourth tie.

The grout mixture consisted of 1 sack of cement to 8 cu. ft. of medium fine Oklahoma City sand and 30 gal. of water, with an admixture of ½ gal. of asphalt emulsion. During an average day, the machine used about 50 sacks of cement and

grouted 100 to 150 lin. ft. of single track. General views of the equipment and operations are shown in Fig. 9. The grain-size distribution of the grouting sand is shown in Fig. 10.

Results

Fig. 8 illustrates conditions encountered in a trench which was excavated about one month after grouting. There was little penetration of the ballast, but a seam of grout extended across the entire section below the ballast. Several grout seams outside of the ties cut through the subgrade and extended to the ditch line. In this area an average of 2.75 cu. ft. of grout per track foot was injected. This value is close to the average for the 8000 ft. of track that had been grouted up to the time the trench was excavated.

As yet there is no information regarding the effect of grouting on maintenance costs, but the amount of maintenance has been reduced in the grouted sections.

Organization

The work was done by a crew of 15 men for a single machine. One foreman and 4 equipment men were furnished by the contractor, and one foreman and 9 laborers by the railroad. There was very little loss of time because of the construction of the machine and the simplicity of connections. Breakage of grout points was very uncommon even though solid points were not used to open holes in the dense ballast.

Atchison, Topeka, and Santa Fe Near Olathe, Kans.

General

The track stabilization project described in this report is a continuous, out of face job extending from M.P. 14 to M.P. 26 in the vicinity of Olathe, Kans. In this area the double-track railroad constitutes the main freight line west of Kansas City and has been carrying a heavy volume of traffic for the past several years. Starting at Holliday, Kans., the track rises throughout the 12 miles to Olathe and follows the edge of a bluff practically all the way.

The subgrade material is composed of medium brown clay and clay shale and a black clay borrow, underlain by formations of limestone, sandstone and shale. Table 1 gives the physical characteristics of some of the subgrade samples taken at depths ranging from 2 to 4½ ft. below the grade.

Table 1.—Physical Soil Constants of Subgrade

Description	*M.P.*	*Liquid Limit*	*Plastic Limit*	*Plasticity Index*	*Shrinkage Limit*	*Water Content*
Black clay	23–19+50	49.5	22.7	26.8	....	32.3
Brown clay	23–19+50	48.2	18.7	29.5	....	23.6
Yellow clay	20–13	42.0	22.5	19.5	13.6	29.2
Yellow clay	20–13	....	....	....	18.9	22.1
Yellow clay	20–13	64.5	22.6	41.9	17.8	33.6
Yellow clay	20–13	36.3	23.2	13.1	9.7	35.6

Note.—The water content is defined as the weight of water in a specimen of soil divided by the dry weight of the soil. It is usually expressed as a percentage. The liquid and plastic limits are, respectively, the upper and lower boundaries of the range in water content within which a soil is plastic.

According to these data, the subgrade would be classified as an inorganic clay of medium to high plasticity.

The original ballast consisted of slag and cinders, but this material has been overlaid successively by limestone and chat ballast. The present ballast section varies in thickness from 3 ft. between the tracks to 4½ ft. at the ends of the ties. The limestone ballast in normal track is very dense. In slide areas, the ballast is porous in the upper 3 ft.

Olathe hill has been a section of high maintenance cost for several years. Examination of the subgrade disclosed soft clay pockets with relatively high water content immediately below the ballast section. In some places, the lower part of the ballast section was badly fouled with clay. In addition, the old slag and cinder ballast was saturated with water and occasionally free water existed.

From Olathe to Holliday, known locally as Olathe hill, 10-in. perforated metal pipe underdrains were installed in 1929 between the tracks on curves. These underdrains were removed prior to the grouting to prevent filling them with grout and also so they could be cleaned and replaced in conjunction with the laying of new rail and track surfacing. They were originally placed at an average depth of two feet below the surface of the ballast. Upon examining several of the drains after removal, it was found that in some areas they were filled with a blue silty material and were inoperative. In several instances the drains were open but were not operating because they had shifted in position both vertically and laterally. Water was found around the drains in several areas. In most cases, the drains that were in good condition functioned only during heavy rains and carried the early runoff.

In several areas, French drains were installed at various times. The functioning of drains of this type has been fair to poor, but they did not seem to stabilize the roadbed effectively.

In 1945, a comprehensive program of cement grouting was initiated to stabilize the roadbed. At the same time, new ballast and rails were placed.

Grouting Procedure

Seven Koehring heavy-duty machines and three company-built machines have been used to do the grouting. Each grouting crew has two machines. The company machines are of the displacement type consisting of a locomotive air ram with a modified piston mounted vertically on the side of a heavy-duty International crawler tread tractor. An Ingersall–Rand compressor operating from the power take-off at the rear of the tractor furnishes air pressure to operate the grout pump and to drive the grout points. The unit is not self-contained, but the grout is mixed separately in a Kwik-Mix model 6 mixer of ½ bag capacity from which it flows by gravity into a slurry box and thence to a well surrounding the air ram. The equipment is illustrated in Fig. 15.

Koehring grout points were driven at a 30-deg. angle 1 ft. from the end of every fifth tie on each side of the track, staggered so that actually every other tie was grouted (see Fig. 13). Each track was treated separately, but 6-ft. points were used between the two tracks and 10-ft. points were used on the outside. Where the ballast pockets were hard enough to break the standard grout points, solid 1½-in. hard points were driven by an auxiliary crew using a separate air compressor of 65 cu. ft. per min. capacity and a 72-lb. jack hammer. Stakes were driven in these holes after the 5-ft. hard points were removed, to keep the holes open until the grouting crew arrived.

The grouting points were driven by means of a jack hammer, and as a point was driven the slurry was forced through it to provide a jetting action. No attempt was made to stop the point when the slurry started to disappear from around the collar of the hole, but the point was driven to the full depth of 6 or 10 ft., depending on which length of point was used.

In general, a grout mix of 1 part of standard portland cement to 12 parts of Kaw River sand, with 1.2 gal. of emulsified asphalt and 40 to 45 gal. of water was used in this section. In some very soft spots or slide areas, a 1:6 mix was used. The mechanical analysis of two representative samples of the grouting sand is shown in Fig. 11.

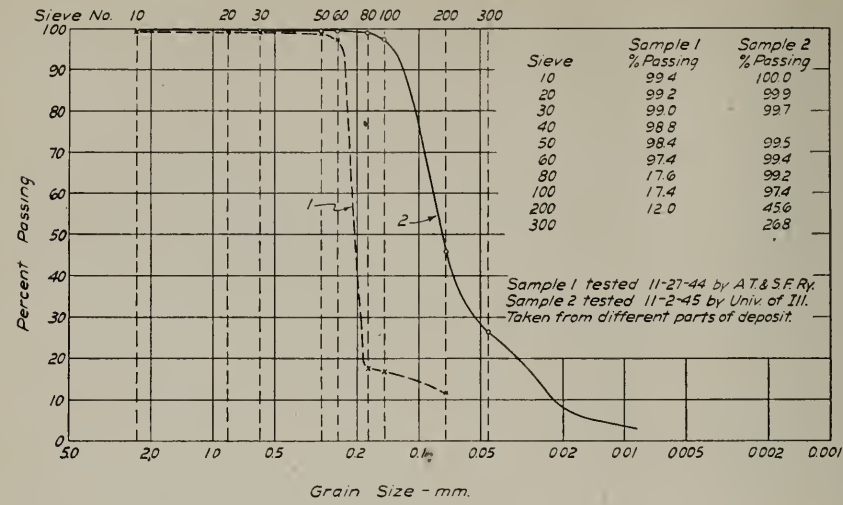


Fig. 11.—Mechanical Analysis of Grouting Sands—Santa Fe.

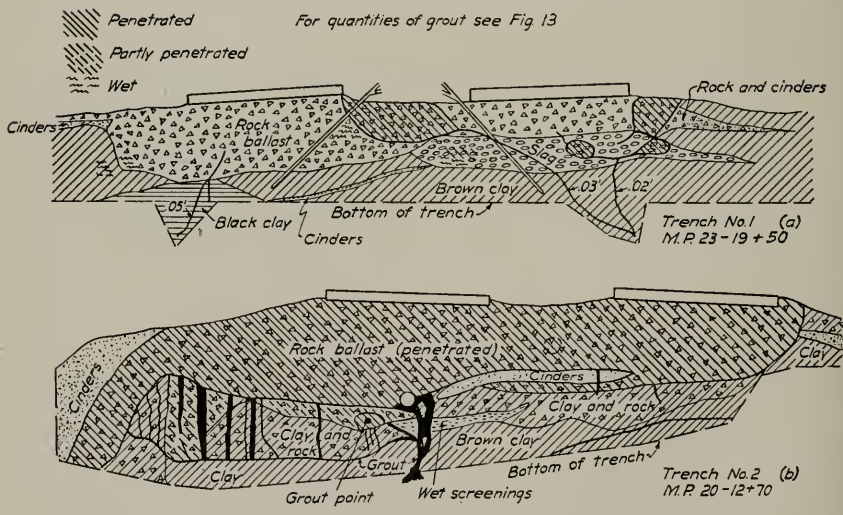


Fig. 12.—Results of Grouting Operations, Santa Fe, Near Olathe, Kans.

Three test trenches dug transversely beneath the track were excavated for the purpose of learning the position of the hardened grout. One of these (Fig. 12a) was located in a typical section in which the average amount of grout injected was 2 cu. ft. per track foot. Another (Fig. 12b) was in a cut-fill section at which sliding movements had taken place for many years. An examination of Fig. 12a shows that in some spots the grout penetrated the upper three feet of the ballast, provided it was free of fine material, to the extent of leaving a thin coating over the rock. However, the wet pockets in the

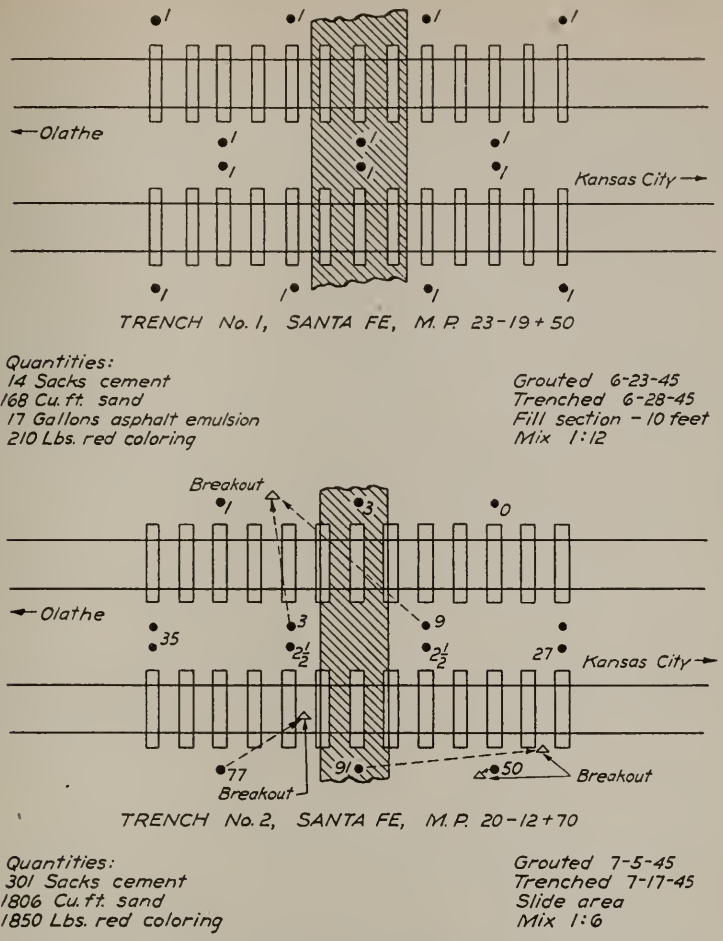


Fig. 13.—Location of Trenches.

ballast were not grouted, and no penetration of the clay or fine material was obtained. The grout was usually found to exist in seams 0.01 to 0.10 ft. thick, distributed at random through the ballast and the subgrade. The grout points were located in the clay subgrade, and grout found its way upward through small channels to the ballast. However, there did not appear to be any sealing of the ballast from the subgrade.

Trench 2 was in a slide area on a sidehill cut-fill section. During wet seasons or after a rain, it was necessary to realine and raise the track, and at times to maintain a watchman at this location. An examination of Fig. 12b shows that the grout penetrated the upper part of the ballast section where the ballast was free of fine material, but in the lower part where the material was fouled with cinders, little penetration was obtained except for streaks running more or less vertically in the form of pipes.

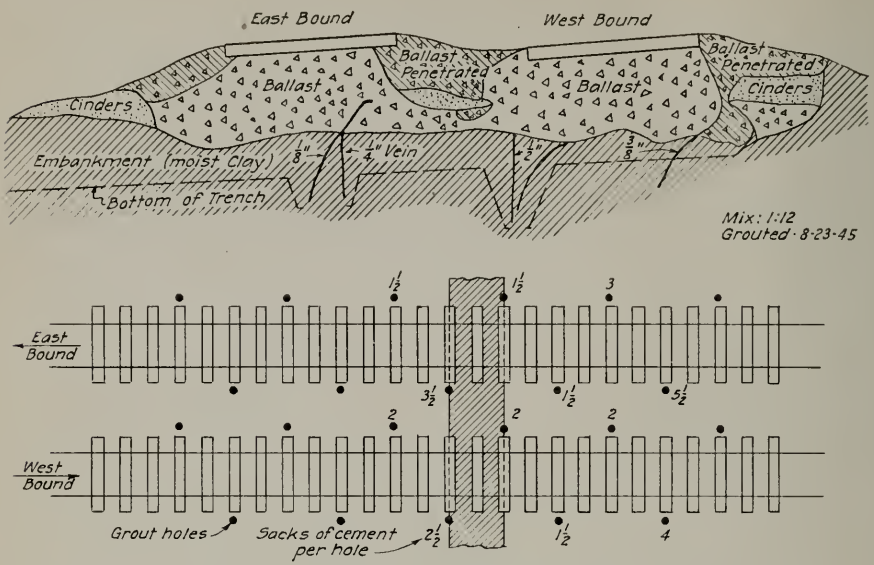


Fig. 14.—Conditions at Trench No. 3.

The locations of trenches 1 and 2 with respect to the location of grout points are shown in Fig. 13. Other data, such as the quantities injected, are also shown on this figure.

A third trench (Fig. 14) disclosed conditions somewhat similar to those at trench 1. The penetration of the ballast was confined to the upper part of ballast section beside but not beneath the tracks.

Table 2 shows the water content of samples of the subgrade taken shortly before and after grouting in a normal section. The water content at the time of sampling (June and July) was between the liquid and plastic limits, and was not materially altered by grouting. However, it was obvious from inspection of the trenches that the water content of clay which had worked out of the subgrade and into the lower part of the ballast section was much greater than that of the samples taken several inches below subgrade level.

Table 2.—Water Content of Subgrade Before and After Grouting

M.P.	*Depth (Ft.)*	*Water Content (% Dry Weight)* *Before*	*After*
19–44+50	2.5–3.0	22.0	....
19–44+50	3.0–3.5	27.0	27.1
19–44+50	3.5–4.0	....	26.2
18– 8+75	3.0–4.0	20.4	20.4

Table 3, which shows the deflections of a test section of track under a light and a heavy wheel load before and after grouting, indicates that the grouting procedure did not significantly increase the modulus of track support. Although the average deflection under a light wheel load was apparently reduced by grouting from 0.091 in. to 0.050 in.,

Fig. 15.—Left and Below—Two Views of the Company-Built Machine; View of Mixer at the Right.

and similarly the deflection under a heavy wheel load was reduced from 0.215 in. to 0.162 in., the difference in deflection between the light load and the heavy load was not significantly changed. The average values before and after grouting were 0.124 in. and 0.112 in.

Table 3.—Deflection of Track Before and After Grouting

Measurements made on 10 successive tie plates under one rail. Deflections in inches.

Plate	*Before Grouting*			*After Grouting*		
	L	*F*	*F–L*	*L*	*F*	*F–L*
1	0.02	0.15	0.13	0.06	0.20	0.14
2	0.13	0.25	0.12	0.06	0.16	0.10
3	0.04	0.18	0.14	0.04	0.13	0.09
4	0.11	0.26	0.15	0.06	0.16	0.10
5	0.11	0.21	0.10	0.03	0.14	0.11
6	0.07	0.19	0.12	0.07	0.17	0.10
7	0.16	0.28	0.12	0.04	0.14	0.10
8	0.09	0.28	0.19	0.07	0.20	0.13
9	0.13	0.22	0.09	0.04	0.17	0.13
10	0.05	0.13	0.08	0.03	0.15	0.12
Average	0.091	0.215	0.124	0.050	0.162	0.112

L denotes light wheel load.
F denotes heavy wheel load.
M.P. 18–9

Comments on Results

The Santa Fe has been stabilizing track in this vicinity by grouting since 194? when the roadbed between Ottawa Junction and Emporia, Kans., was first grouted. It is the opinion of the enginemen and section men that the riding qualities of the roadbed in that section have been improved and the amount of maintenance reduced. The railway officers are convinced that the grouting has been economical from the standpoint of reduced maintenance costs.

To provide greater flood clearance, the grade of one section of the roadbed west of Ottawa Junction has been raised four feet by the addition of a sand fill. This offers an opportunity to determine the extent to which the roadbed can be stabilized by the placement of a sand cushion.

It must be pointed out that in the grouted sections as well as the area of the sand cushion, the track has been improved by the placement of additional ballast and heavier rail. Furthermore, the track has been surfaced and realined. These facts make it difficult at the present time to assess the benefits actually derived from the grouting.

Organization

Each outfit of two machines was generally assigned 0.7 miles of track for each set up. Each machine could grout about 320 lin. ft. of single track per day per grout line. One 150-ft. grout line was available on the company built machine, and two 150-ft. lines on the Koehring machines.

The grouting crews were supplied with material by a special worktrain assigned to the job. When water was not available along the right-of-way, it was furnished from tank cars.

Grouting operations are under the supervision of the district engineer, and are the direct responsibility of the division engineer who furnishes a field engineer to direct the work. The work of each outfit of two machines is supervised by the foreman and his assistant. The grout is prepared by the machine operator and his helper with the aid of

Fig. 16.—Left—Driving and Pulling Hard Points; Right—View of Trench No. 1.

four laborers. A crew of four men is assigned to the job of driving and pulling the hard points, and the actual grouting is done by a crew of three men. A crew of 12 to 14 men is required for each grout machine. Since about 90 percent of the labor has been imported from Mexico, camps and bunk cars are furnished for the personnel.

New York Central Near Welland, Ont. and Near Vermilion, Ohio

General

This report describes the cement grouting procedure used to stabilize soft spots in the main line of the Michigan Central between Fort Erie and Welland, Ont. Supplementary information is given regarding the results of similar work between Sandusky and Elyria, Ohio. The procedure and equipment described are typical of the grouting which has been done by this railroad on several lines west of Buffalo, N. Y. A rather complete description of the railroad's experience with grouting is available in a pamphlet published February 1945 entitled Pressure Subsurface Grouting on the New York Central System West of Buffalo.

The unstable section which constitutes the principal subject of this report extended between Fort Erie, M.P. 3 and M.P. 8. In this vicinity the double-track line crosses the plain bordering Lake Erie and the Niagara River. The subsoil consists of a plastic glacial clay which in some localities is brown and in others appears to consist of a red layer overlying a blue deposit. In the trench section, Fig. 19, it is not clear whether the red

clay is part of the natural deposit or whether it is fill material. The subsoil of the line between Sandusky and Elyria, Ohio, consists of a partly oxidized blue and yellow glacial clay. The physical properties of samples of these various clays are given in Table 4.

TABLE 4

	Red Clay	*Brown Clay*	*Blue and Yellow Clay*
M.P.	FE 4.32	FE 3.0	SS 2204+17
Liquid limit	34.2	80.0	38.4
Plastic limit	18.4	34.3	25.3

In the following paragraphs the statements refer strictly to the work near Welland, Ont. However, this work does not differ essentially in character from that in Ohio. The ballast material consists chiefly of 2½-in. crushed stone to the depth of about two feet, although in some sections gravel has been used. In many localities, the uppermost foot consists of cinders or a mixture of cinders and crushed stone. Open ditches along the track are fairly deep and often have water standing in them because of the high water table.

The soft spots which have developed in this area do not seem to occur along both tracks, but predominantly along the outside rail of the eastbound track. Ballast pockets have formed beneath the outer 2 ft. of the ties to a depth of 5 to 7 ft.

Grouting Procedure

Before grouting, a careful examination is made by the engineers and maintenance men to ascertain the exact location of each soft spot in the track. Grouting is confined to these spots; no out of face grouting has been done or is contemplated by this railroad. The grouting is done by means of company-built machines of the pneumatic type, having a capacity of 7 cu. ft. The combined grout mixer and pressure tank consists of a cylinder 40 in. long and 20 in. in diameter, placed horizontally on skids so that it can be readily moved. A section through the machine, reproduced from the aforementioned publication, is shown in Fig. 17. The tank contains eight mixing paddles mounted on a shaft driven by a compressed-air motor mounted outside the tank. A charging hole 6 in. in diameter is provided in the top of the tank, and is covered by a quick-fitting screw type cap. Air pressure is supplied to the tank and to the air motor by a compressor with a capacity of 105 cu. ft. per min. This compressor also operates the 72-lb. air hammer used to drive the grout pipe. Air is supplied to the tank at a pressure of 50 lb. per sq. in.

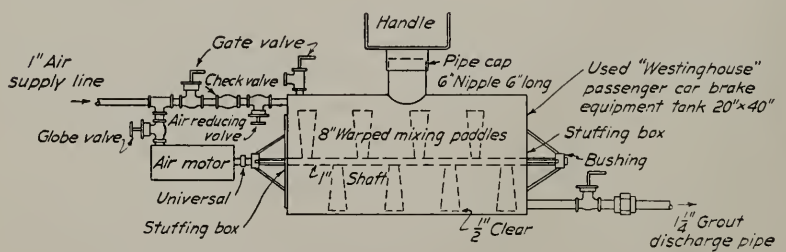


Fig. 17.—New York Central, Mixing and Grouting Tank.

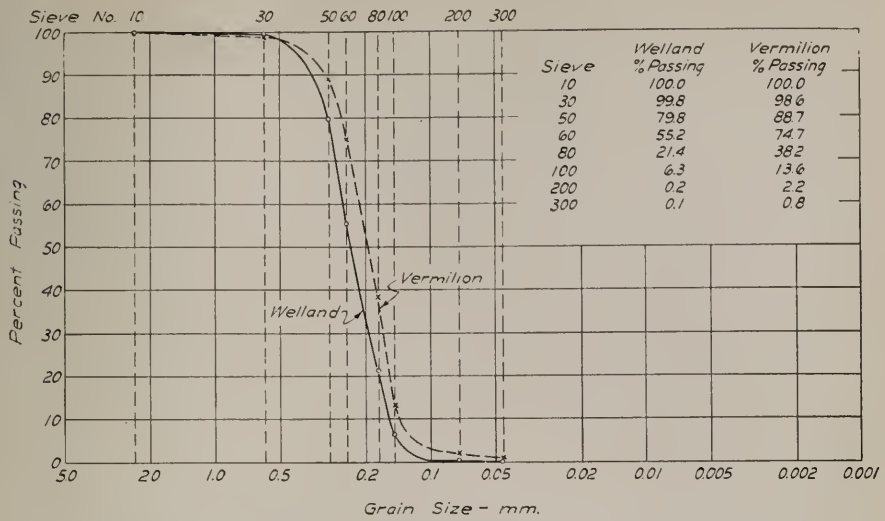


Fig. 18.—New York Central, Mechanical Analysis of Grouting Sands.

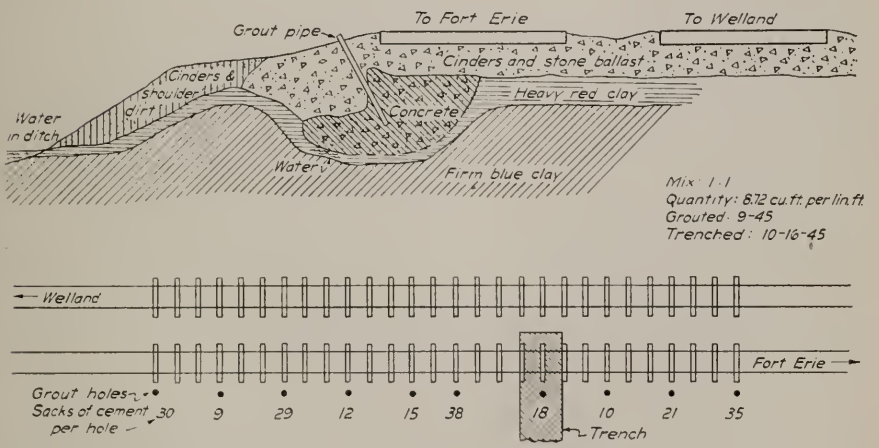


Fig. 19.—New York Central Trench Section and Grout Hole Spacing, Fort Erie, M.P. 4.32.

and valves are appropriately located to control the flow of grout through the discharge line at the lower end of the tank as well as to provide an air escape when the grout line is closed.

The injection points consist of 5-ft. lengths of double strength 1¼ in. iron pipe. Before driving, a track bolt is inserted in each end and a dolly, which fits into the air hammer, is placed over the driving end. Suitable extension pipes of 3-ft. and 4-ft. lengths are provided for use where the 5-ft. pipes do not reach the bottom of the ballast pocket.

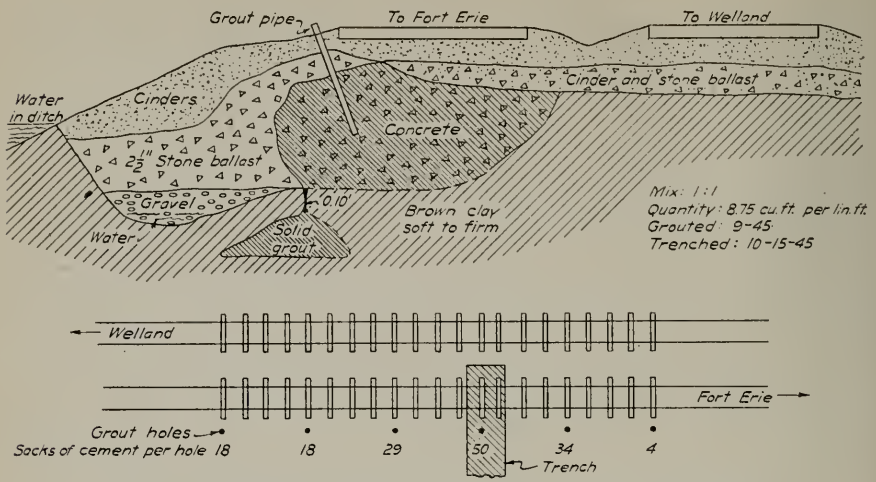


Fig. 20.—New York Central Trench Section and Grout Hole Spacing, Fort Erie, M.P. 3.0.

The pipes are driven at every fourth tie along the outside rail as shown in Fig. 19. Each pipe is driven until it just penetrates into the soft material at the bottom of the ballast section. The bottom bolt is then driven out by means of a rod, and the grout line connected to the top. About eight gallons of water are then poured into the tank and forced into the pipe to wash out the fine material and lubricate the ballast material. It has been learned by experience that this procedure facilitates penetration of the grout. The water is followed by one batch of a very rich mixture—two parts of cement to one of sand, which is intended to form a seal along the top of the subgrade. Finally, the remaining grouting at each pipe is done with successive batches, consisting of 1 sack of cement, 1 cu. ft. of sand, and 8 gal. of water. The grain-size characteristics of the grouting sand are shown in Fig. 18. For each batch the water is first placed in the mixer followed by the sand, and lastly by the cement. Inasmuch as the mixer blades run continually, the batch is mixed by the time the cover can be attached. As soon as the cover is in position, the air is turned on and grouting begins. Since the paddles keep the charge agitated, the stream of grout is broken by slugs of air which can be detected by the surging of the grout hose. These charges of air are considered beneficial.

Grouting is continued at one pipe until the grout begins to break out at the surface, or until a pressure of 50 lb. per sq. in. can force no more grout into the ballast section while the pipe is gradually withdrawn. However, no grout is forced into the ballast with the pipe less than 2½ ft. below the bottom of the ties. The nozzleman is able to tell when the mixer is empty by the feel of the grout line, and immediately signals to the mixer man to cut off the air. The mixer is then recharged and the grouting continued. Because of the small batch sizes and the open type of ballast, several batches are usually required at each pipe. Each machine is able to deliver from 75 to 125 batches of grout in an 8-hr. day.

Results

Figs. 19 and 20 illustrate the roadbed conditions as shown by trenches which were dug after grouting. The amount of grout injected was approximately 9 cu. ft. per track foot at the two locations. The ballast pockets were penetrated by grout which formed a

concrete slab of varying thickness. Penetration was obtained even where the 2½-in. rock ballast had been contaminated with gravel or cinders, although in most cases the ballast which took the grout was relatively open. Fig. 21 shows similar conditions encountered in a trench at Vermilion, Ohio.

To date this railroad has realized substantial maintenance savings by pressure grouting of soft spots. Each grout spot has been carefully marked at both ends with boards which show the spot number and date of grouting. It has thus been possible to keep very accurate records of the maintenance costs before and after grouting as well as the subsequent history of the grouted sections.

The grouting at a given location is usually done by a crew of seven men operating two machines. All of the grouting on the system is under the direction of an assistant engineer. Each machine is manned by an operator, a nozzleman and a laborer. A truck driver furnishes materials to both machines. The machines are usually set up close enough

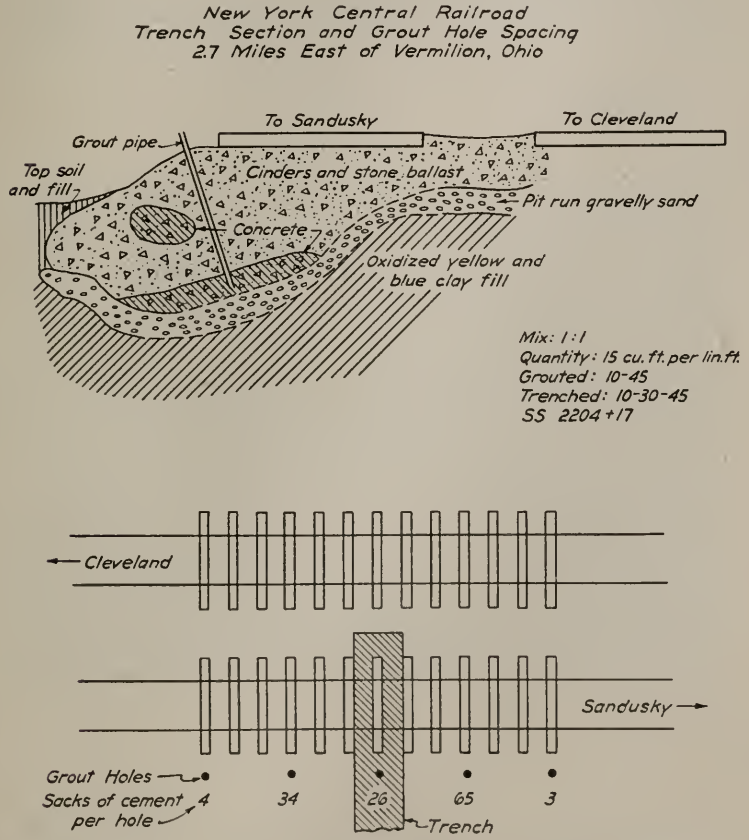


Fig. 21.—New York Central Trench Section and Grout Hole Spacing 2.7 Miles East of Vermilion, Ohio.

Fig. 22.—View Showing Grouting Machine and Other Equipment.

Fig. 23.—View Showing Upper Slab of Penetration Concrete in Trench Excavated Near Vermilion, Ohio.

together so that the men are interchangeable. The foreman of the job acts as a nozzleman. During charging operations the mixer operator is assisted by the nozzleman or the laborer.

Chicago, Milwaukee, St. Paul & Pacific Near Owego, Iowa

General

The track stabilization project described in this report extends from M.P. 69.3, near the station at Owego, Iowa, northwesterly for a distance of about 3¾ miles. It is part of a section of single-track line traversing the Missouri River bottom for a distance of 22 miles. The track is paralleled by a drainage ditch on the west side and is separated from the ditch by an earth dike. Water level in the track ditch commonly lies between 5 and 6 ft. below the ties.

The subgrade material used to make the fill sections was taken from borrow pits along the right-of-way. It is a highly plastic black gumbo clay, as evidenced by the physical properties tabulated below for two typical samples.

	Percent	*Percent*
Natural water content	22.5	48.8
Liquid limit	65.0	68.5
Plastic limit	25.7	33.0
Shrinkage limit	12.4	15.9

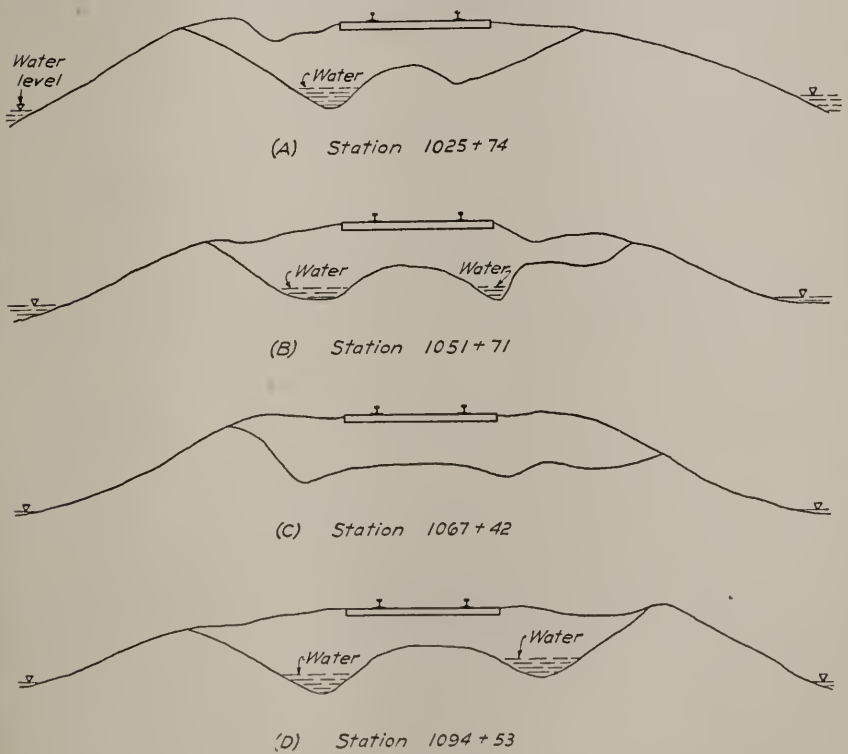


Fig. 24.—Milwaukee Road Near Owego, Iowa, Shape of Ballast Pockets.

A ballast of cinders was placed above the subgrade when the track was originally laid, but the cinders have been dispersed throughout the lower part of the ballast section 2½ to 3 ft. below grade and have been replaced and supplemented by a pit run gravel ballast containing considerable fine material.

Many soft spots have developed in this section of track. Trench exploration before grouting revealed that the ballast pockets vary in depth from 2½ ft. at track center to more than 3½ ft. at the ends of the ties. In an inspection during August 1945, free water was found in the ballast pockets, and the black clay subgrade was soft and wet to a depth of several inches. The shape of several typical ballast pockets is shown in Fig. 24, drawn from data furnished by the railroad.

Grouting Procedure and Equipment

A pneumatic grouting machine actuated by a compressor rated at 210 cu. ft. per min. was used to mix the slurry for the 3¾ miles of track grouted under contract. The machine (Fig. 27-a) was loaded by a skip which supplied a 7-cu. ft. maximum batch to the mixing drum. After mixing, the grout was forced by air pressure out of the drum into the grout lines and pipes. Double-strength grout pipes of 1¼ in. inside diameter were driven by means of a jackhammer to a depth of 5 ft. at every 5th tie on each side of the track, staggered so that grouting took place at every 2½ ties. About 20 to 25 open-end pipes, plugged with loose bolts or rivets, were driven ahead of the grouting crew. Before grouting connections were made to the pipe, the plug was rodded free from the bottom end.

Four air lines were connected to the compressor tank. These served the jackhammer, the skip-hoist motor, the mixer-blade motor, and the grout machine. An adjustable reducing valve with a pressure gage was located at the compressor pressure chamber which supplied the air for grouting. This valve is shown in Fig. 27-b.

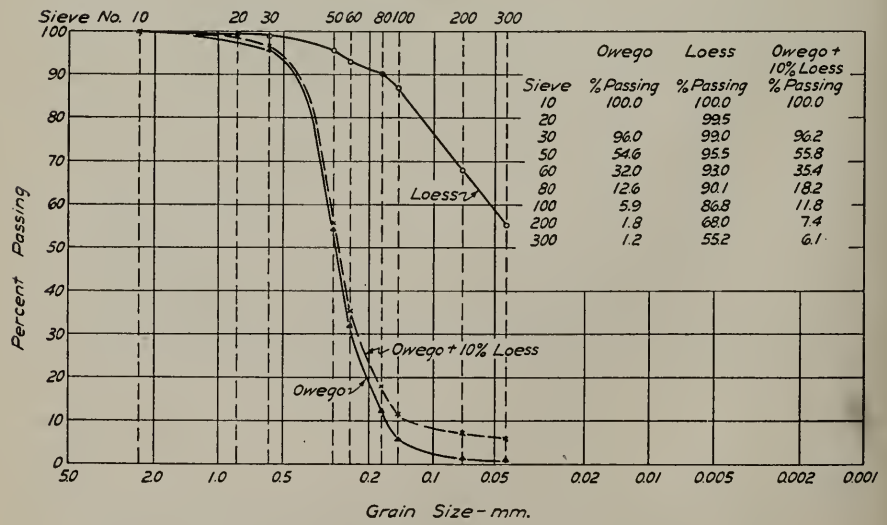


Fig. 25.—Milwaukee Road, Mechanical Analysis of Grouting Sands.

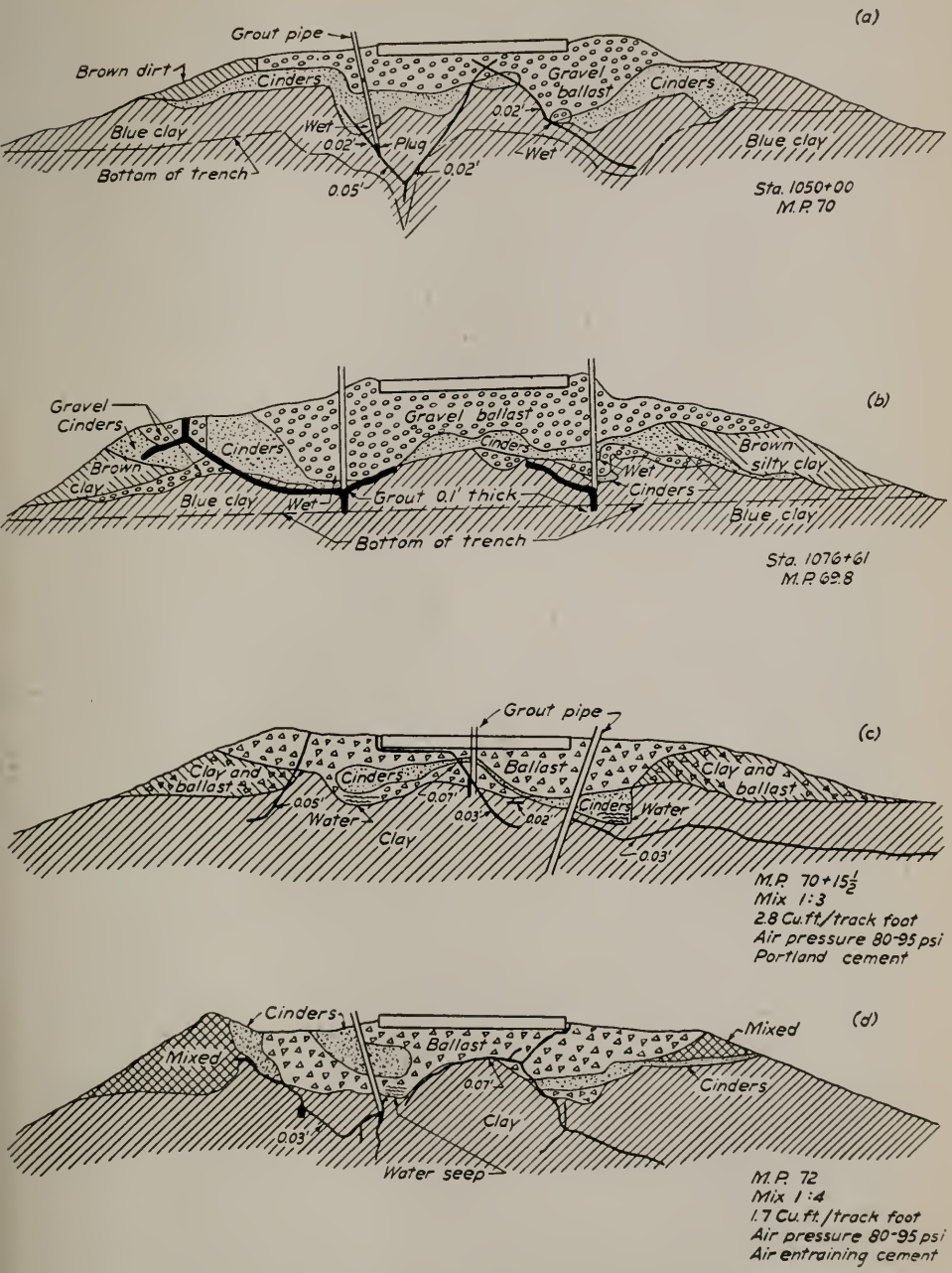


Fig. 26.—Milwaukee Road Near Owego, Iowa, Results of Grouting.

Grouting operations were started using a pressure of about 100 lb. per sq. in. This pressure appeared to be too high, since the grout was forced into the subgrade so rapidly it often broke to the surface at various points. Furthermore, the line frequently became plugged. The pressure was therefore reduced to a value ranging between 60 and 70 lb. Although some breakouts occurred at this pressure, the results seemed to be more satisfactory. A typical breakout is shown in Fig. 27-c.

At the beginning of operations standard portland cement was used in a 1:3 or 1:4 mix with a fine engine sand from Ottumwa, Iowa, and 18 gal. of water per sack of cement. Because of difficulties with segregation, the mix was changed by using air-entraining cement or by blending the sand with 10 percent loess. The grain-size analyses of these materials are shown in Fig. 25.

Various modifications of the procedure were made from time to time. Among these was the driving of an additional grout pipe between every third tie between the rails for a distance of about 1500 ft.

Results

Trench examination of sections of the roadbed after grouting indicated that the grout did not fill the voids in either the old or new ballast in the wet pockets. On the contrary, it was found to lie in seams varying in thickness from 0.01 to 0.10 ft. These

Fig. 27-a.—View of Pneumatic Grouting Machine—Milwaukee Road Near Owego, Iowa.

Fig. 27-b.—Adjustable Reducing Valve for Controlling the Air Pressure.

Fig. 27-c.—Typical Breakout of Slurry Through the Ballast.

seams were not continuous across the roadbed, but usually lay between the subgrade and the ballast and sometimes extended at random through the clay and ballast to the surface. Fig. 26 shows a cross section at each of 4 trenches excavated after grouting.

The use of air-entraining cement and 10 percent loess added to the engine sand apparently improved the grout mix, giving it a smoother texture so that it could flow freely, and reducing segregation of the materials.

The quantity of grout injected varied from 0.90 to 1.60 cu. ft. per linear foot of track. In the 1500-ft. section where additional grout pipes were inserted between the rails, the quantity of grout was about 2.6 cu. ft. per linear foot.

Organization

During an average 10-hr. day, in the sections where grout pipes were not added between the rails, about 180 lin. ft. of track were grouted, using the following equipment:

1 .....210-cu. ft. per min. air compressor
1 .....mixer, air actuated, 9-cu. ft. capacity
1 .....72-lb. jackhammer
200 ft. .....2-in. iron pipe for main grout line
125 ft. .....1¼-in. rubber grout line
400 ft. .....1-in. rubber air hose
1 .....water pump
Small tools such as shovels, wrenches, pipe puller, etc.

The work was done under the direct supervision of an engineer representing the railroad and a foreman representing the contractor. The mixing was done by one mixer operator with the help of four laborers. The grouting was done by one nozzleman with two helpers, and the grout pipe was driven and pulled by one jackhammer man with two laborers.

Conclusion

The studies made so far have been undertaken to learn (1) the conditions under which unstable roadbeds due to ballast pockets develop, (2) the details of the grouting procedures now in use to correct the conditions, and (3) the manner in which the grout is distributed within the roadbed after injection. In addition, the records serve to form the basis for judging the success of the grouting operations as maintenance records are accumulated for the locations which have been studied. By restricting the scope of the investigation to these subjects, the studies have been kept on a practical level and preconceived opinions regarding the various aspects of roadbed stabilization have been avoided.

It is of interest to note that the subgrade material at every location studied in the investigation consists of clay of medium to high plasticity. No sands, silts, or even silty clays have been encountered below ballast pockets. This fact is illustrated by Fig. 28, which represents a plasticity chart useful for classifying clays, after A. Cassagrande. In this chart, the vertical axis refers to values of the plasticity index (numerical difference between liquid limit and plastic limit), and the horizontal axis to values of the liquid limit. The chart is divided into six regions, each representing the type of soil indicated on the figure. The type of a given soil is determined by the region in which the point representing its limit values falls. Points corresponding to the subgrade samples tested during the investigation are appropriately identified.

If the formation of ballast pockets is confined to subgrades of plastic clays, the investigation will be materially simplified because it is likely that the results of grouting operations will be fairly independent of the type of soil.

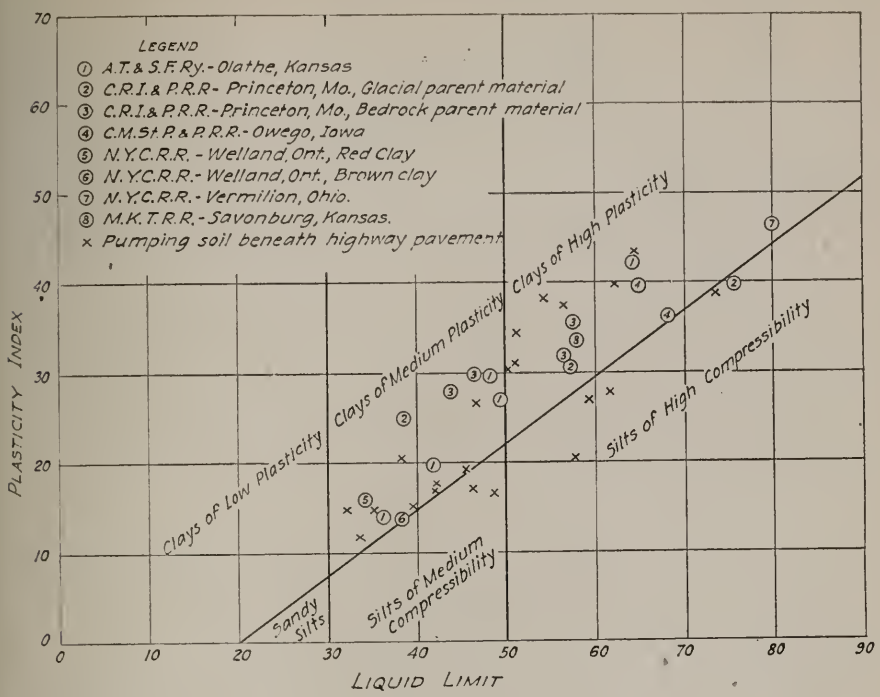


Fig. 28.—Soil Plasticity Chart.

To obtain further information in this connection, a survey has been made of the literature dealing with the pumping of concrete pavements, a highway problem which appears to be closely related to the formation of ballast pockets. The points indicated by crosses in Fig. 27 represent soils responsible for the pumping of highway pavements in various parts of the United States (see Proceedings of the Highway Research Board, 1943, page 310). It is apparent that, with few exceptions, the points representing soils subject to pumping fall within the same general area occupied by those representing soils from the soft spots studied in this investigation. The exceptions occurred in the far south, where differences in the conditions of weathering are known to lead to the development of unusual soil types. These facts suggest that a deliberate effort should be made to learn whether, in northern latitudes, soft spots have occurred in any types of soil except clays of medium to high plasticity, and that, in addition, studies should be made on railways in the south to ascertain whether any special conditions occur in that part of the country.

Up to the present time, it has been the intention to avoid all speculation concerning the manner in which the grout accomplishes its desirable effects. Failure or partial failure of any of the test sections is likely to disclose the physical processes involved, in far more convincing fashion. Hence, it has been the principal aim to record all facts which may be pertinent, with the expectation that within a reasonable length of time the facts will lead to an understanding of the nature and value of the grouting process.

Report on Assignment 5(b)

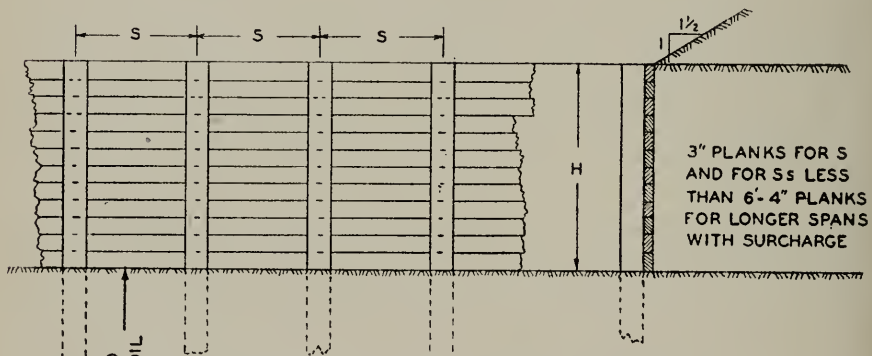
Structural Support; Struts; Piling

Treatment of retaining structures begins on page 1–66.01 in the Manual under the heading and subheadings

603. RETAINING STRUCTURES
A. CRIBBING
B. WALLS

The present assignment covers a third and last section—Structural Support; Struts; Piling.

This report is submitted as information with the recommendation that the subject be continued with the hope that it may be presented to the Association next year for inclusion in the Manual. Criticisms and suggestions for improvement are solicited.



IF 12" MIN. DIA. PILES ARE SPECIFIED		
HEIGHT H	SPACING.	
	S	Ss
9 FT.	2'6"	
8 FT.	3'0"	
7 FT.	4'0"	
6 FT.	5'6"	2'6"
5 FT.	8'0"	3'6"
4 FT.	10'0"	5'6"
3 FT.	10'0"	10'0"
OR LESS		

IF 14" MIN. DIA. PILES ARE SPECIFIED		
HEIGHT H	SPACING	
	S	Ss
10 FT.	2'6"	
9 FT.	3'0"	
8 FT.	4'0"	
7 FT.	6'0"	2'6"
6 FT.	8'0"	3'6"
5 FT.	10'0"	5'6"
4 FT.		9'0"
3 FT.		10'0"

Fig. 1.—Typical Piling Retaining Structures.
For walls without surcharge use spacing in Column S; for walls with surcharge use spacing in Column SS.

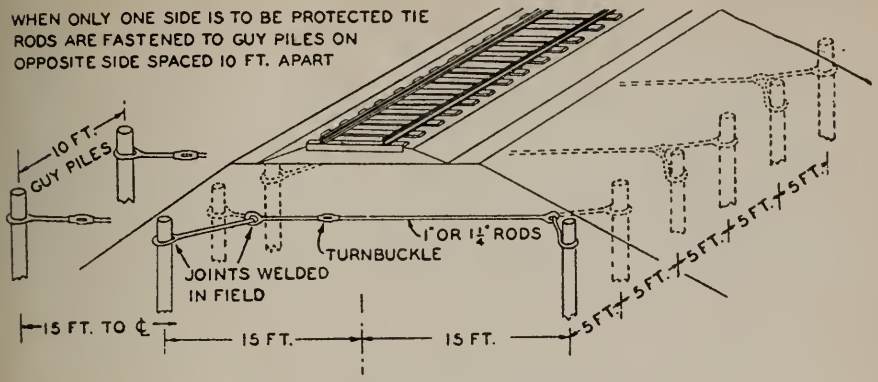


Fig. 2(a).—Piling Bound with Tie Rods.

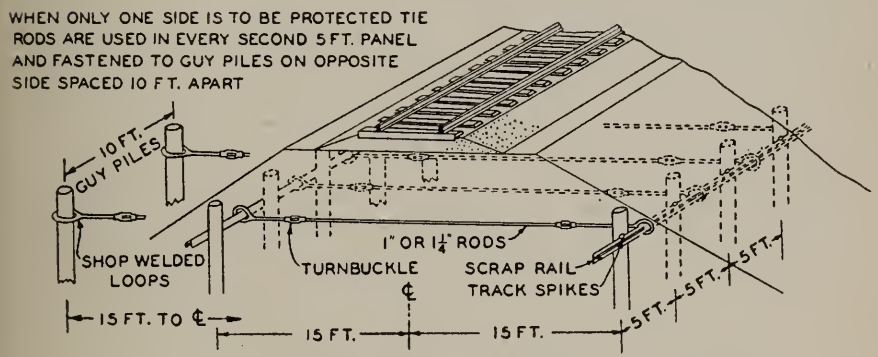


Fig. 2(b).—Piling Bound with Scrap Rail and Tie Rods.

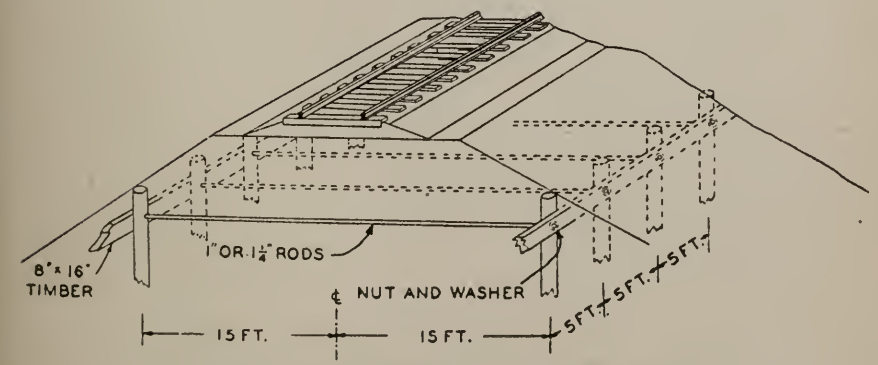
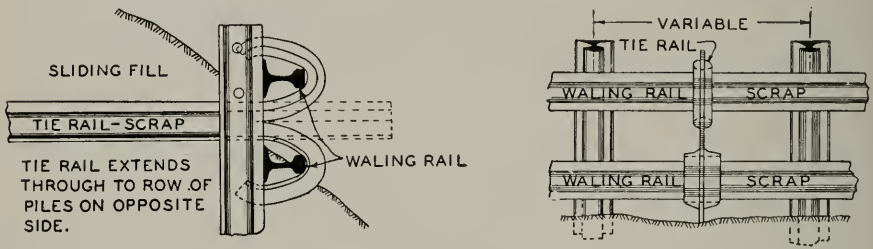


Fig. 2(c).—Piling Bound with Timbers and Tie Rods.

C. STRUCTURAL SUPPORT; STRUTS; PILING

Pile retaining structures may be built quickly with minimum excavation, making them particularly adaptable in emergencies, against soft slopes where continuous caving would result if excavation were made for other types, or where an excavation cannot be made without disturbing structures or improved property.

The illustrations shown are for ordinary conditions. The actual design for a particular place should be modified to meet any special conditions known to be existing, and give consideration to experience with any similar structures in the vicinity.



Side Elevation — Front Elevation

Fig. 3.—Scrap Rail Piling and Tie Rails.

Driving rails—heaviest available.
Waling rails—medium weight.
Tie rails—lightest available.

Note.—Split tie rail in center of web by burning, bend head and base around waling rails as shown.

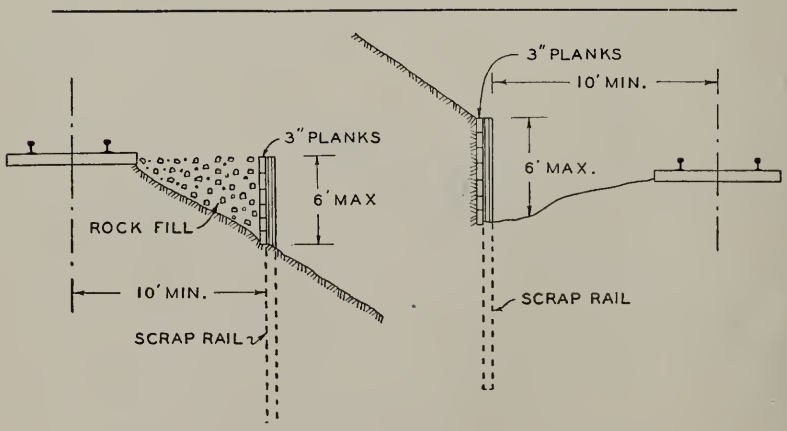


Fig. 4.—Scrap Rail Piling and Timber Retaining Wall.

Timbers fastened to the rails by ⅛-in. by ¾-in. scrap iron back of the timbers with a wire wrapped around the strap and the rails.

Timber

Fig. 1 shows a typical timber pile retaining structure with a table showing the spacing of piles without surcharge and with sloping surcharge.

Three-inch planks will have sufficient strength to carry the earth loads in bending between piles in any case without surcharge, although 4-in. planks may be preferred for pile spacings of 8 ft. or more. Thinner planks in contact with earth would be undesirable. With surcharge, planks may be 3 in. for spans less than 6 ft. For spans 6 ft. to 10 ft., 4-in. planks are required.

In fairly firm soils, a pile penetration equal to the projection above the ground is often sufficient, although from 3 ft. to 10 ft. additional penetration is recommended.

Strutted posts may be used instead of piling where the soil is fairly firm, and space is available for the struts. This type is only used for low walls, or in emergencies where other materials or necessary equipment is not at hand.

Sliding Slopes

Piling has been driven extensively to protect the roadbed where sliding fills or slips occur. This is sometimes considered as stabilization of roadbed, but actually the piles act to retain the roadbed, rather than as stabilization.

Fig. 2 shows three different methods of tieing timber piling together for protection in sliding fills. There are many modifications. Effective temporary protection was obtained in one instance where there was a sliding fill on one side, on a sloping rock ledge, and a rock bluff on the opposite side of double track. Steel pile points were used to secure a toe hold in the rock, two 8-in. by 16-in. waling strips at the top, with tie rods to special anchors sunk in rock on the bluff side.

Scrap rails may be used instead of timber piling. Method of tieing them together is shown in Fig. 3. A combination rail piling and timber retaining wall, as shown in Fig. 4 may be used to advantage for the conditions indicated.

A study of the conditions, together with an inventory of available materials, should be made to determine the method to be used.

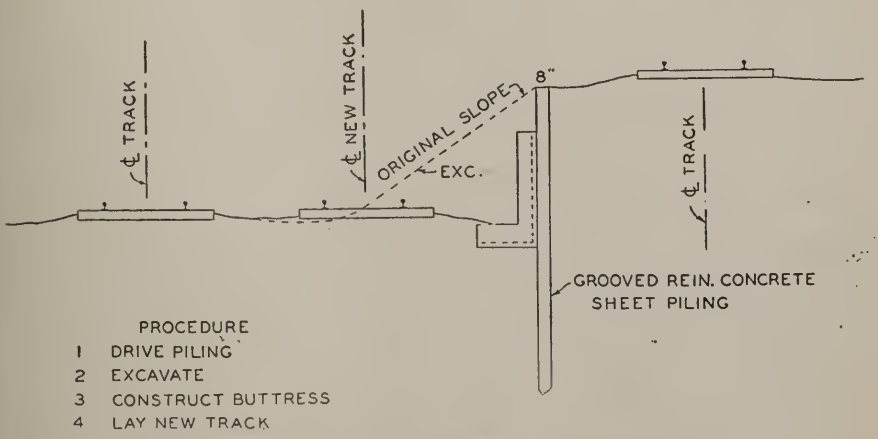


Fig. 5.—Use of Grooved Reinforced Concrete Sheet Piling.

Concrete

Concrete piles with reinforced concrete planks have been little used except as back walls at bridge ends, but such structures may be designed for heights up to 20 ft. that will meet all requirements for stability and long life. A complete survey and soil analysis should be made available so that the designer may prepare detailed plans for each such structure.

Grooved reinforced concrete sheet piling may be used and is particularly adaptable in places where excavation cannot reasonably be made in advance, as in Fig. 5. Such structures have their limitations, especially where they carry live load surcharges, and a special design must be made for each location. A buttress at the ground line will add to their stability.

Steel sheet piling may be used instead of concrete, but where such structures are required cinders and other corrosive elements are too often present and such structures are not recommended for general use in roadway protection.

Report on Assignment 8

Signs—Specifications and Plans for Telltales—Overhead and Side

L. J. Drumeller (chairman, subcommittee), G. H. Burnette, J. M. Fair, H. G. Johnson, G. L. Morrison, J. M. Podmore, W. J. Turner, P. H. Winchester, S. M. Jackson.

Last year your committee presented as information, a tentative draft of specifications for one and two-track overhead wood warning and wood side warning (Proceedings, Vol. 46, 1945, pages 514 to 517, inclusive). These specifications are now submitted with recommendations that they be adopted and published in the Manual. The committee also recommends, that the plans appearing in the Proceedings, Vol. 46, 1945, pages 515 and 516 be also published in the Manual as part of the specifications.

Report on Assignment 9

Ballast Specifications

Stanton Walker (chairman, subcommittee), T. A. Blair, H. F. Brown, W. J. Cable, A. P. Crosley, A. T. Goldbeck, F. W. Hillman, J. R. Scofield, C. S. Wicker, Edward Wise, Jr.

This report is presented as information.

Since the preparation of the Specifications for Prepared Stone, Slag and Gravel Ballast adopted in 1944, the subcommittee on specifications has developed no recommendations requiring action by the Association. So far as its present assignment is concerned, it is felt that the subcommittee must function pretty much in a standby position until additional information is developed—for the most part information on test methods. The purpose of this report is to discuss the current specifications for ballast and to point to desirable improvements in them which depend on refinements or modifications in testing procedures.

The recommendations of the specifications most readily evaluated are those covering grading. Grading is a tangible characteristic on which almost everyone dealing with

ballast has an opinion. It affects economy of production and many features of the roadbed such as uniformity of support of track, stability, drainage, resistance to fouling, pumping joints, etc. The review of specifications conducted in 1943, and published in the Proceedings, Vol. 44, indicates that most of the formal specifications issued by individual railroads are consistent with the spirit of AREA recommendations. That appears to represent tangible evidence that the suggested gradings are satisfactory. However, relatively few railroads have incorporated AREA recommendations bodily in their specifications and many railroads, which have modeled their specifications closely after AREA recommendations, have not taken into account recent revisions. It is suggested that, in the interest of simplified practice, railroads be urged to reexamine their specifications in the light of the current AREA recommendations.

Quality requirements for hardness, strength, durability, etc., are less readily evaluated than grading requirements. A problem always before the specifications and testing engineer is that of the significance of tests as related to performance in service. Ballast specifications, in common with other specifications, fall short of drawing a completely accurate line of demarcation between satisfactory and unsatisfactory materials. That, in part, is because of inadequacies in test methods and, in part, because the suitability of a given ballast may depend on conditions of use. More work needs to be done on this phase of the ballast specifications, much of which must await the development of further information.

The quality requirements of the current AREA specifications for prepared ballast include limitations on:

(a) Soft and friable pieces
(b) Resistance to abrasion
(c) Soundness
(d) Material finer than No. 200 sieve
(e) Clay lumps
(f) Weight per cubic foot (in the case of slag only)

It should be of interest to discuss briefly the significance of each of these factors.

Soft and Friable Pieces

Excessive quantities of soft and friable pieces are undesirable because they are likely to be unsound and will break up under pressure. They contribute to fouling, pumping joints, etc. The current specification limits the quantity of such pieces to 5 percent; *but* what constitutes a "soft and friable piece?"

There is no generally recognized standard for determining soft and friable pieces. Various methods have been standardized, which depend on resistance to impact or pressure, but they have been discarded one after the other. Until 1938 the American Association of State Highway Officials had a Method of Test for Quality of Soft Pebbles in Gravel. That method is based on pressure, a soft piece being defined as one which will crush under a load of 35 to 75 lb. depending upon the size of the piece. Only obviously soft pieces fail under this test. The test method was discontinued by the American Association of State Highway Officials because it was thought to be, although correct in principle, not sufficiently severe for highway materials. Committee 1 of the AREA continued it as a test for ballast, pending the development of a better method, because of the feeling that it may be more significant as a measure of ballast quality than of aggregates used in the portland cement and bituminous concretes of highway construction.

Research work is being continued in the development of a method of test for soft pieces. Most of such work is under the jurisdiction of appropriate ASTM committees, on certain of which the AREA is represented.

The Los Angeles rattler test offers some promise of affording a measure of soft pieces. The standard test for resistance to wear is made with 500 revolutions of the machine. When this test method was first introduced it was proposed to measure wear at 100 revolutions as well as at 500 revolutions. That procedure had for its purpose the development of information on soft pieces, since obviously, they will break up more quickly than the harder ones comprising the principal portion of the sample.

Research on this procedure was allowed to lapse, but interest in it now seems to be reviving. Some state highway departments specify limits at both 100 and 500 revolutions. At least one state fixes an upper limit at 500 revolutions on the poorest 15 percent of the material, as determined visually, and also a limit on the average sample. Consideration has been given to establishing a limiting ratio of the 100 revolution loss to the 500 revolution loss, but that is complicated by the differences in its significance, depending upon the shape of aggregate particle.

Wear

The test for percentage of wear using the Los Angeles rattler is a combination impact and abrasion test which furnishes overall information on the hardness and toughness of the ballast and other mineral aggregates. The test consists of, in effect, subjecting a sample of material to the action of a small ball mill, with an abrasive charge of steel balls, under standardized conditions. The test results are believed to be of considerable significance.

Unfortunately, the Los Angeles test method, as thus far standardized by the ASTM, does not provide for testing the larger sizes of ballast and of many road materials. The coarsest sample for which provision is made is graded between 1½ and ⅜ in. Thus, for example, the procedure does not cover stone ballast sizes No. 24 (2½ in. to ¾ in.), No. 3 (2 in. to 1 in.), or No. 4 (1½ in. to ¾ in.). The highway field is just as much handicapped as the ballast field by the incompleteness of the test method.

This inadequacy in scope of the method is not due to lack of attention. Considerable research has been done on it—and recently. The difficulties which have been encountered may be somewhat hard to explain clearly; they arise from the strong desire to maintain the same specification limits for different gradings of samples. Four different gradings are now standardized—the coarsest being the 1½ to ⅜ in. just mentioned and the finest being graded between the No. 4 and No. 8 sieves. Abrasive charges for these various gradings of samples are specified to be of such weight that substantially the same percentage of wear is obtained for different gradings of the same material. The attempt has been to attain that same result for coarser samples, either by variations in amount of abrasive charge or in number of revolutions.

These attempts now seem doomed to failure unless modifications are made in the testing machine. The way would appear to be open for the establishment of an arbitrary test method which will require different specification limits for the coarser sizes than for the finer ones. That approach is now under consideration by an ASTM committee.

Having solved the testing procedure problems, there will still remain the problem of appropriate specification limits. The current specifications suggest a maximum of 40 percent of wear. Undoubtedly, that limit admits certain ballasts which are not as good as others for some uses. A lower limit would bar from use many good ballasts. The realistic thing to do, it would appear, is to fix specification limits to fit local conditions.

Soundness

The soundness test is designed primarily as a measure of the ability of the ballast to resist freezing and thawing. The current specifications suggest that it be applied only in regions where freezing temperatures are expected. The method of test specified is a simulated freezing and thawing test involving alternate immersion in a sodium sulfate solution and drying in an oven. The formation of the sodium sulfate crystal in the interior of the aggregate piece furnishes the disruptive force and simulates the disruptive force exerted by ice.

The test method is fairly well standardized and the results of tests are reasonably well reproducible. The test appears to be fairly significant. At least it can be said that materials meeting it are almost invariably sound. On the other hand, some materials failing to meet it have given good results in service.

Material Finer than the No. 200 Sieve, Clay Lumps and Weight per Cubic Foot

The methods for determining material finer than the No. 200 sieve and of clay lumps are fairly well standardized and are complicated only by difficulties in obtaining completely representative samples. These tests are mainly checks on the cleanness of material.

Limitations on weight per cubic foot apply only to slag. The test is readily made and its results are reproducible. Its purpose is to eliminate from use some of the less dense and more friable materials.

Concluding Remarks

This report will have served its purpose if it makes clear why the specifications subcommittee needs to continue being on the alert, although considerable time may elapse before it is in a position to make new recommendations on specifications requiring action by the Association. Much dependence must be placed on the progress of the subcommittee on tests for ballast and, also, on the progress of appropriate committees of the ASTM which have for their function the development of test methods.

Report on Assignment 11

Ballast Tests

(a) Studies of Test Methods

A. T. Goldbeck (chairman, subcommittee), George Auer, Jr., L. H. Bond, C. B. Bryant, J. E. Chubb, L. H. Jentoft, O. N. Lackey, W. C. Sneed, C. S. Wicker.

This is a progress report presented as information.

Subcommittee 11 deals with tests relating to ballast and up to the present time these tests have been those used for specifying quality. The service conditions to which railroad ballast is exposed are not unlike those of highways and since the quality tests for aggregates were developed initially for highway use it seemed logical to adopt these tests for determining the quality of railroad ballast. Thus, the AREA specifications in the past have included the Deval abrasion test, the toughness test, the Dorry hardness test, the cementing value test and only recently those older physical tests for quality, involving principally the fundamental properties of hardness and toughness, have been replaced by the Los Angeles abrasion test.

The Los Angeles abrasion test is a test which presumably determines in one operation the suitability of the ballast. It simulates the impact and abrasion forces of service to an unknown extent. A steel drum, 28 in. in diameter and 20 in. long revolving on a horizontal axle and having a single, longitudinal, radial, steel shelf 3½ in. wide comprises the testing machine. The sample, composed of plant-produced, graded aggregate, weighs 5000 grams and with it is used a charge of steel shot approximately 1⅞ in. in diameter. Five hundred revolutions of the drum, requiring about 16 min., are specified. The percentage of loss is determined from the material passing the U. S. Standard No. 12 sieve.

There are several investigations which could be undertaken with profit regarding the use of the Los Angeles abrasion machine for testing railroad ballast. They may be described briefly as follows:

1. At present the test sample may consist of one of four gradations: 1½ to ⅜ in., ¾ to ⅜ in., ⅜ to No. 4 and No. 4 to No. 8. Obviously, the last two gradations are never applicable to ballast, the ¾ to ⅜ in. rarely so, and the 1½ to ⅜ in. comes closest to the AREA ballast sizes. But even this gradation is not entirely suitable, for no doubt the greatest tonnage of ballast is of larger sizes such as 2½ to ¾ in. or 2 to 1 in. There is at present no standard Los Angeles sample involving these large sizes and, further, there is no established relationship between percentage of loss when samples of widely different gradations are used. This means that it is possible that aggregates having the same Los Angeles abrasion loss using a 1½ to ⅜ in. sample may have quite different losses when a 2½ to ¾ in. or other larger diameter material is used, and different materials in large sizes may give different service results, even though the abrasion loss is identical in the present standard test. The investigations thus far made give no assurance that any relationship exists between samples containing large pieces and those made up entirely of small pieces.

2. Although an attempt was made by your subcommittee in the period from 1937 to 1942 to correlate service behavior of ballast with the Los Angeles abrasion loss by means of questionnaires, this attempt was not successful in establishing any well defined relationship between Los Angeles abrasion loss and service value. The 40-percent limit at present used in the AREA specification is based more on judgment than on established fact.

3. The above facts lead to the probable desirability of standardizing several more gradations and abrasive charges to be used therewith, the gradations to be as follows:

Passing *In.*	*Retained on* *In.*	*Weights in Grams* *Grading E*	*Grading F*
2½	2	1250	....
2	1½	"	1667
1½	1	"	"
1	¾	"	"

It is suggested that samples having the above gradations be used with a charge of 12 spheres of standard size; also with 15 and 18 spheres in a further attempt to determine the proper number to use.

4. Standardization of a test does not establish the desirable percentage of loss for use in ballast specifications. This must be done on aggregates whose service behavior is known. But service value depends upon many variables such as character of tamping tools, intensity of traffic, possibly track design and possibly other variables including the judgment of the person reporting service value. Accordingly, it is suggested that perhaps an approach to the question of relative service value may be made by means of

special tamping tests combined with repeated load applications through wood ties using for this test a special testing machine whose essential details may consist of the following:

A box or bin capable of accommodating approximately 5 ties spaced in a standard manner, but of half the usual length. A standard heavy rail section is to be attached to these ties which in turn are to be supported on the ballast to be tested.

The test will consist of repeated applications to the rail of a heavy concentrated load, the settlement being continuously measured or graphically recorded. After a given settlement is reached, the track will be raised back to its original position and the repeated loading process and tamping will be repeated through a sufficient number of cycles to cause some degradation of the ballast. Finally, the track structure will be removed, the ballast sampled and the amount of degradation determined. Los Angeles abrasion tests made on the various ballasts used would correlate the Los Angeles loss with this simulated field behavior of the ballast.

The possible advantages of such a test would be:

(1) The test could be performed relatively quickly.
(2) Extraneous and uncontrolled variables, such for illustration as subgrade effects, would be eliminated.
(3) The machine, if designed with foresight, could be used for other studies such as subgrade pressures under different loading conditions, useful for determining proper depth of ballast.
(4) Preliminary studies could be made on possible treatments of ballast to shed surface water and to minimize clogging.

Such a test would require the shipping and handling of large samples of ballast, perhaps 5 tons each and because of the nature of the test the machine would be heavy and costly, but if it can be made adaptable to researches of the nature above indicated, there are strong possibilities of benefit which would make the cost of the investigation relatively insignificant. The next step would be to have preliminary designs prepared for the testing device in cooperation with the research staff of the Engineering Division. The above is a preliminary suggestion which future study may greatly modify.

Soundness or Weather Resistance of Ballast

At present the soundness of ballast is determined by the accelerated sodium or magnesium sulfate test. The significance of this test as now applied to ballast has not been definitely established. All ballasts are not exposed to equally severe weathering and hence there need not be a universal soundness requirement as at present. Further, the actual significance of the accelerated soundness test requires further investigation. Some materials fail in the test and do not fail in service and there are other materials which are unsound, but which are relatively sound as indicated by the accelerated test. This matter should be looked into if ultimately a thoroughly satisfactory specification is to be obtained.

Briefly, the above summarizes some of the desirable researches in the ballast field. Personnel and financial assistance and a definite research plan could greatly speed the procurement of the needed facts. Without these, facts will have to be obtained gradually and incompletely and your committee will have to continue to rely on its best judgment in the writing of specifications and in the making of designs.

Report of Committee 4—Rail

W. H. Penfield, *Chairman*,
J. B. Akers
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S. E. Armstrong
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Barton Wheelwright
R. P. Winton
J. G. Wishart
Louis Yager
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including revisions recommended for adoption and publication ..... page 367

2. (a) Further research, including details of mill practice and manufacture as they affect rail quality and rail failures, giving special attention to transverse fissure failures and other defects in the head, web and base, collaborating with Rail Manufacturers' Technical Committee.

   Progress report, presenting twelfth progress report of the rails investigation page 467

   (b) Specifications for thermal treatment of rail, such as control cooled, Brunorized, etc.

   No report.

3. Compilation of Statistics.

   (a) All rail failures, making special study of transverse fissure failures.

   (b) Compilation of statistics for determining the performance of control cooled and Brunorized rail in service with respect to rail failures, with the view toward evaluating the higher price paid for treated than for untreated rails.

   Progress report on entire assignment, presented as information..... page 378

4. Cause and prevention of rail battering and methods of reconditioning rail ends.

   No report.

5. Economic value of different sizes of rail.

   No report.

AREA Bulletin 458, February 1946.

6. Continuous welding of rail, collaborating with Committee 5—Track.

Progress report, presented as information..... page 392

7. Service tests of various types of joint bars.

Progress report, presented as information..... page 394

8. Investigate joint bar failures and give consideration to the revision of design and specifications.

Progress report, presented as information..... page 411

Appendix 8-a, fourth progress report of the rolling load tests of joint bars.. page 414

9. Corrugated rail—causes and remedy. Effect upon riding qualities of tracks and upon the costs of track and equipment maintenance.

Progress report, presented as information..... page 427

10. Development and characteristics of fractures under engine burns in rail, together with investigation as to the effectiveness of welding up engine burns by oxyacetylene or electric methods.

Progress report, presented as information..... page 430

11. Investigate causes of shelly spots and head checks in rail surfaces for the purpose of developing measures for their prevention.

Progress report, presented as information..... page 432

Appendix 11-a, report of field stress measurements by the research staff... page 435

Appendix 11-b, fourth progress report of the shelly rail studies at the University of Illinois ..... page 443

12. Investigate recent developments affecting rail section.

Progress report, presented as information..... page 448

Appendix 12-a, study of 131-lb. rail..... page 449

Appendix 12-b, stress measurements of various modified rail sections..... page 449

Appendix 12-c, report of fatigue tests of rail webs at the University of Illinois ..... page 464

13. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A —General Reclamation of the Purchases and Stores Division, AAR.

No report.

The Committee on Rail,
W. H. Penfield, *Chairman.*

Report on Assignment 1

Revision of Manual

C. B. Bronson (chairman, subcommittee), W. H. Penfield, J. E. Armstrong, W. C. Barnes, C. H. Blackman, W. J. Burton, Armstrong Chinn, J. L. Gressitt, G. F. Hand, G. W. Harris, E. M. Hastings, F. S. Hewes, Maro Johnson, B. R. Kulp, F. R. Layng, G. M. Magee, E. E. Oviatt, A. N. Reece, J. C. Wallace, Barton Wheelwright, Louis Yager.

Your committee has made a critical study of the definitions in the Glossary of the Manual and recommends the following changes, additions and deletions:

Minor Revisions

Bessemer Converter.—Change the word "furnace" to "receptacle."

Bessemer Process.—Change the words "through it in a furnace" to read "through the metallic bath in a converter."

Burrs.—Delete the word "hot."

Carbon Steel.—Change the last three words "presence of carbon" to read "percentage of carbon in the steel."

Elongation.—Insert the word "gage" after "original."

Heat or Melt.—Add "of the melting furnace" at the end of the definition.

Micrograph.—Add the following to the definition to make this the same as for "Macrograph." The words to be added are: When it is desired to indicate that it is a photographic reproduction, the term "photomicrograph" may be employed.

Open Hearth Furnace.—Change the words "may be" to read "is generally."

Segregation—Positive.—Change the words "(in solution)" to read "during solidification."

Steel.—Change "1.50" to "1.70."

Major Revisions

Acid Open-Hearth.—Steel made by the open-hearth process in a furnace lined with acid or siliceous material. Because of the character of the furnace, an acid slag must be employed for refining the bath in this process. Since phosphorus and sulfur are not removed by an acid steel making process, the metallic charge must be made up of specially selected pig iron and scrap.

Alloy Steel.—Steel containing more than 1.65 percent manganese or more than 0.60 percent silicon or other elements added for the purpose of modifying or improving the mechanical or physical properties normally possessed by plain carbon steel.

Basic Bessemer.—Steel made by the bessemer process in a furnace having a basic lining, usually either magnesite or burned dolomite. Phosphorus is oxidized and removed in the basic slag but the removal of sulfur is uncertain. Basic bessemer steel is not produced in the United States due to the fact that iron ore of high phosphorus content is not available.

Basic Open-Hearth.—Steel made by the open-hearth process in a furnace lined with basic material, usually of either magnesite or burned dolomite. The refining slag employed in the basic open-hearth process is a basic slag and has the ability to remove phosphorus from the metal. The base is provided by limestone included with the pig iron (either solid or molten) and the steel scrap making up the furnace charge. Since phosphorus (and, to a limited extent, sulfur) is removed from the

metallic bath by a basic slag, it is not necessary to use special low phosphorus pig iron in the charge as is the case with an acid process.

Billet.—A semifinished product of a blooming or billet mill, either square or rectangular in section, and having a maximum cross-sectional area of 36 sq. in. and a minimum cross-sectional dimension of 1½ in.

Bloom.—A semifinished product of a blooming mill having a cross-sectional area greater than 36 sq. in., the usual form being square or rectangular in cross section and special forms being designated as round and shape blooms.

Canting of Rail.—Change this to "cant" to read as follows:

Cant.—The inclination inwardly of a rail, effected by the use of inclined surface tie plates or by inclined dapping of ties, usually expressed as a rate of inclination, such as 1 in 40, etc.

Charge.—The molten pig iron placed in a bessemer convertor, or the solid or liquid pig iron, steel scrap, limestone and other materials placed in the open-hearth furnace for conversion into steel.

Crushed Head.—A "flattening" or crushing down of the head.

Cropping.—Cutting metal from the end of an ingot, bloom or rail during the process of rail manufacture.

Detail Fracture.—A progressive fracture originating at or near the surface of the rail head. These fractures should not be confused with transverse fissures, compound fissures or other defects which have internal origins. Detail fractures usually have their origins in the following types of defects, and progress crosswise into the head of the rail.

1. *Shell*—Where a thin shell of metal becomes separated from the head, usually at the gage corner.
2. *Head Checks*—Usually at or close to the gage corner where movement or flow of surface metal is sufficient to start a hairline crack.

Ordinary Break (Square or Angular Break).—Any partial or complete fracture in which there is no sign of a fissure, and in which none of the other defects or damage described on Form 402–A under the heading of "Description of Rail Failures" is visible.

Piped Rail.—One with a vertical split, usually in the web, due to failure of the sides of the shrinkage cavity in the ingot to unite in rolling.

Rail Section.—The shape of the end of a rail cut at right angles to its length. The rail mills identify the different shapes and types of rails by code numbers, as for example 131–28 for the 131-lb. RE rail section.

Soaking Pit.—A vertical reheating furnace in which the ingots, after being stripped, are placed in an upright position for the purpose of uniformly reheating them to the temperature required for rolling.

Split Web.—A lengthwise crack along the side of the web and extending into or through it.

Yield Point.—That unit stress in a material at which there occurs a marked increase in strain without an increase in stress, as determined by (a) drop-of-beam method, (b) using dividers, or (c) using extensometers.

New Definitions

Branding.—The identification markings hot rolled in raised figures and letters in the rail web indicating the weight of rail and section number, type of rail, kind of steel, name of manufacturer and mill, and year and month rolled.

Brunorized.—A patented heat treatment for rails consisting essentially of normalizing the steel. (Named in honor of John Brunner, Carnegie–Illinois Steel Corporation.)

Cast Iron.—Alloys of iron containing 1.7 percent to 4.5 percent carbon as cast, and usually not appreciably malleable at any temperature.

Cast Steel.—Any object made by pouring molten steel into molds.

Cold Shut.—A defect produced during casting of molten metal which may result from splashing, surging, or interrupted pouring. It may be due to any factor that will prevent a perfect union where two surfaces meet that should fuse and blend.

Compromise Joint.—A rail joint using joint bars designed to connect rails of different fishing height and section.

Control Cooled.—A method of controlling the cooling rate of steel products. For rails this is accomplished by placing 75 to 150 rails in an insulated container.

Corrugated Rail.—A rough condition on the rail tread of alternate ridges and grooves, which develops in service.

Discard.—The top and bottom portions of the ingot which are hot sheared after blooming, with the object of insuring clean and sound metal in the finished steel products.

End Hardening.—The methods of heat treatment of the tread of rails at the ends to minimize rail batter.

Endurance Limit (Fatigue Strength).—The highest unit stress whose repeated application can be indefinitely endured without failure, or a limiting stress below which metal will withstand without fracture an indefinitely large number of cycles of stress.

Drop Test.—The method of determining the ductility and impact resistance of finished metal shapes using a fixed weight falling from a predetermined height and delivering a blow or shock to the metal shape while resting on supports attached to an anvil.

Ingot Mold.—A cast metal form, either square or rectangular in section, and usually six feet or more in height, into which the molten steel is poured or teemed for the purpose of solidification. The mold rests on a cast metal stool or base, mounted on a buggy, for transfer to the stripper and soaking pits.

Lap.—A surface defect on metal appearing as a seam caused from folding over hot metal, fins, or sharp corners and then rolling or forging, but not welding them to the surface.

Normalizing.—Heating iron-base alloys to approximately 100 deg. F. above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

Rail (Track).—A rolled steel shape, commonly a T-section, designed to be laid end to end in two parallel lines on cross ties to form a track for railway rolling stock.

Scab.—A rough projection on a casting caused by a mold breaking or being washed by molten metal; or occurring where the skin from a blowhole has partly burned away and is not welded.

Segregation Streaks.—Small strings or bands in steel containing an excess of nonmetallic or oxidized impurities running lengthwise. The segregated streaks are generally more brittle, weaker and harder than the surrounding metal.

Seam.—A crack on the surface of metal which has been closed but not welded; usually produced by blow holes which have become oxidized.

Service Kinked Rail.—A rail having an indentation downward and usually sideways indicating damage by locomotives with unbalanced drivers.

Shatter Cracks.—Minute cracks in the interior of rail heads, seldom closer than ½ in. from the surface, and visible only after deep etching or at high magnification. They

may extend in any direction. They are caused by rapid (air) cooling, and may be prevented from forming by control cooling the rail. Shatter cracks also occur in other steel products.

STAMPING.—The figures and letters indented after hot sawing in the center of the rail web, parallel with the direction of rolling, indicating the serial heat number, the ingot number as cast or rolled, and one letter designating the position of each rail with reference to the top of the ingot.

Deletions

Cinder Heat
Commercial Iron
Lumpy

Minor Revisions of Forms and Figures

In a critical check of the various forms and figures in the Manual under Committee 4—Rail, certain minor changes are desirable to bring them up to date, and the recommended changes are as follows for the form or figure number, and Manual page as indicated:—

Form 401–A, page 4–42—Delete the last column headed "Rail Indentation Test on Head of Rail". Also change "Manufacture's Chemical Analysis" to "Manufacturer's Chemical Analysis". Add "Rev. 1946" after "Form 401–A".

Form 401–B, page 4–43—In headings "Calculated weight, etc.", change word "Not" to the word "Hot" ahead of the words "Trial Weight". Change column headings "Lbs." to read "Lb." Add "Rev. 1946" below "Form 401–B".

Form 401–D, page 4–45.1—In heading change "Controlled Cooling" to read "Control Cooling". Also change wording of footnote to read "Temperatures are in degrees fahrenheit. The hours to 300 deg. under 'Drawing' is that indicated by thermocouple located between an outside and adjacent rail in the bottom tier. For cases where the thermocouple is in the middle tier show letter M in front of the time in column—Hours to 300 deg." Change abbreviations "Hrs." in column headings to read "Hr." Add "Rev. 1946" under "Form 401–D".

Form 402–A, page 4–46—On front page change revision date from 1942 to 1946. On reverse side change captions to read "Detail Fracture—Shell" instead of "Shelly" and also "Detail Fracture—Head Check", instead of "Head Check".

Also change description of detail fracture to read as follows:

DETAIL FRACTURE.—A progressive fracture originating at or near the surface of the rail head. These fractures should not be confused with transverse fissures, compound fissures or other defects which have internal origins. Detail fractures usually have their origins in the following types of defects, and progress crosswise into the head of the rail:

(1) Shell—Where a thin shell of metal becomes separated from the head, usually at the gage corner. See Fig. 7.

(2) Head Checks—Usually at or close to the gage corner where movement or flow of surface metal is sufficient to start a hairline crack. See Fig. 8.

Also change description of square or angular break to read:

ORDINARY BREAK (Square or Angular Break).—Any partial or complete fracture in which there is no sign of a fissure, and in which none of the other defects or damage described on this form is visible. See diagrams 15 and 16.

Form 402–C, page 4–47—Revise heading of column to read "Comp. Fiss., Det. Fract," Engine Burn Fract." instead of "Comp. Fiss., Det. Fract. from Engine Burns, Shells, etc.". Change revision date from 1944 to 1946.

ASSOCIATION OF AMERICAN RAILROADS
ENGINEERING DIVISION

Form 402-C
Rev. 1946

Rail Failures for Year Ending Dec. 31, 19__ Railroad_____ Sheet No. of

Mill & Kind of Steel	Year Rolled and Yr. Laid	Section and Lb. per yd.	Gross Tons New Rail Laid	Equiv. Track Miles	Miles Years	Period	Trans. Fiss.		Comp. Fiss., Det. Fract. Engine Burn Fract.		V.S.N. and H.S.N.	Other Head	Broken	Web		Base	All Types
							Serv.	Det.	Serv.	Det.	Total	Total	Total	In Joint Total	Other Total	Total	Total
						This Yr. Total											
						This Yr. Total											
						This Yr. Total											
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In filling out this form, follow instructions on Form 402-C (a) Rev. 1946
This form when filled out should be returned to W. C. Barnes, engineer of tests, Association of American Railroads, 59 E. Van Buren St. Chicago, 5, Ill.

Form 402–C(a), page 4–48—Item 3, change the words "Compound Fissures and Detail Fractures originating from wheel burns, shells, flow and head checks, etc." appearing in third and fourth lines to read "Compound Fissures, Detail Fractures and Engine Burn Fractures." Also words "Comp. Fiss., Det. Fract. from Engine Burns, Shells, Etc." to read "Comp. Fiss., Det. Fract., Engine Burn Fract." Also in the tabulated example shown in Item 16, page 4–49, change the number 5 appearing in column headed "Equiv. Track Mi." opposite December 31, 1941 to read 10. Change revision date from 1944 to 1946.

Form 402–L, page 4–50—Change words "Compound fissured, and detail fractured rail from engine burns, shell, flow and head checks, etc." to read "Compound fissured, detail fractured and engine burn fractured rails." Change "Issued 1944" to read "Rev. 1946."

RECOMMENDED PRACTICE FOR RAIL INSPECTION

(Manual pages 13 and 14)

It was initially pointed out that Section 206 of the Recommended Practice For Rail Inspection was at variance with actual practice. After further review and consultation it became apparent that the entire subject matter on rail inspection is not in conformity with the practices of individual railroads nor that of inspection bureaus and it is therefore recommended that the Recommended Practice for Rail Inspection be eliminated from the Manual.

SPECIFICATIONS FOR HEAT-TREATED CARBON STEEL AND ALLOY-STEEL TRACK BOLTS

(Manual pages 29 to 32, inclusive)

There has been considerable demand to broaden Section 13—Threads and Thread Fit—to provide for both wrench fit and the Class 2 or hand-free fit. As the result of a careful canvass that included consultation with the manufacturers of track bolts, it is now recommended that the following be substituted for the present Section 13 for this specification in the Manual:

13. Threads and Thread Fit

The threads on bolts and nuts shall conform to the American National form of thread as shown on page 12 of the American Standard Screw Threads, B1.1–1935. Either a free or wrench turn fit shall be furnished at the option of the purchaser in accordance with the following provisions:

(a) *Free fit.*—The threads of the bolts and nuts shall conform as nearly as practicable to the American Standard limits for tolerance prescribed for the Coarse Thread Series—Free Fit (Class 2) Screws and Coarse Thread Series—Free Fit (Class 2) Nuts.

(b) *Wrench turn fit.*—The nut shall have a free fit for at least two threads in starting on the bolt and when fully engaged and for the remainder of the screw length shall show the following minimum and maximum resistance to turning as expressed by pounds of pull applied to the end of a 24-in. wrench:

	Minimum (Lb.)	*Maximum* (Lb.)
Regular nuts (3b)	5	45
High strength nuts (3c)	5	55

Before packing, nuts shall be screwed on the bolts enough turns to hold them in place until used.

SPECIFICATIONS FOR OPEN-HEARTH STEEL GIRDER RAILS OF PLAIN, GROOVED, AND GUARD TYPES

GIRDER RAIL SECTIONS

(Manual pages 4–57 to 4–69, inclusive)

Because there is a limited demand for girder rails for steam railroad use, and also because both the specifications and designs are readily available in pamphlet form through the American Transit Engineering Association for those desiring this information, it is recommended that the Specifications For Open-Hearth Steel Girder Rails of Plain, Grooved, and Guard Types, and the Rail Sections be eliminated from the Manual.

SPECIFICATIONS FOR OPEN-HEARTH STEEL RAILS

(Manual pages 4–1 to 4–5, inclusive)

Steel rails for the railroads in the United States and Canada are now principally specified to be manufactured under the control cooling process. The provisions for recommended control practice are now only available by reference to the Proceedings and do not appear in the Manual. In view of this situation, it seemed highly desirable to embody

the control cooling features in the rail specifications, at the same time review the various sections, and make such changes and additions as were considered desirable in the light of present requirements and practices. Meetings held by the Contact Committee, Rails Investigation, have afforded an opportunity to obtain the viewpoint of the rail manufacturers on various features incorporated in the specifications.

It is therefore recommended that the following Specifications for Open Hearth Steel Rails be substituted for those now in the Manual. The revised specifications are as follows:

SPECIFICATIONS FOR OPEN-HEARTH STEEL RAILS
1946

I INSPECTION

101. Access to Works

Inspection and tests shall be made at the works of the manufacturer before shipment, and the works management shall afford all reasonable facilities for determining the quality of the rails produced.

II CHEMICAL REQUIREMENTS

201. Chemical Composition

The chemical composition of the steel, determined as prescribed hereafter, shall be within the following limits:

Constituents	*Nominal Weight in Lb. per Yd.*		
Percent	70–90	91–120	121 and over
Carbon	0.64–0.77	0.67–0.80	0.69–0.82
Manganese	0.60–0.90	0.70–1.00	0.70–1.00
Phosphorus (Max.)	0.04	0.04	0.04
Silicon	0.10–0.23	0.10–0.23	0.10–0.23

202. Average Carbon

In any rolling it is desired that the number of heats above the mean carbon percentage of the specified range shall be at least equal to the number of heats below the mean, and that the average carbon shall be as high as the mean.

203. Analyses

Separate analyses shall be made from drillings taken from test ingots representing one of the first three and one of the last three full ingots of the heat to determine the percentage of carbon and manganese. The percentage of phosphorus, sulfur, and silicon shall be determined on equally mixed drillings from the test ingots. The average analysis of the ladle test ingots shall conform to the chemical requirements. A portion of the drillings shall be furnished to the inspector upon request for check analysis.

III PHYSICAL REQUIREMENTS

301. Ductility and Resistance to Impact

(a) Ductility and resistance to impact shall be determined by the standard AREA drop testing machine, with test specimens from 4 ft. to 6 ft. long cut from the top of the "A" rails from the second, middle and last full ingots of each heat. Temperature of the test specimens shall not exceed 100 deg. F. The distance between supports shall be 3 ft. for sections under 106 lb. For sections 106 lb. to 140 lb. it shall be 4 ft. For sections over 140 lb. it shall be 4 ft. 8 in.

The test specimens shall be placed head upwards on the supports and subjected to one blow from the top falling free from the following heights for rails of the nominal weights indicated:

Weight per Yd., Lb.	*Ft.*
70–80, inclusive	17
81–90, inclusive	18
91–100, inclusive	19
101–120, inclusive	20
121, and over	22

(b) If all these specimens withstand the above test without fracture, all of the rails of the heat will be accepted subject to final inspection for surface, section and finish.

If one of the 3 specimens fails, all the "A" rails of the heat shall be rejected. Specimens shall then be cut from the bottom end of the same "A" rails or the top end of the "B" rails of the same ingots and tested. If any of these specimens fail, the "B" rails of the heat shall be rejected. Three additional specimens shall then be taken from the bottom end of the "B" rails or the top end of the "C" rails of the same ingots. If none of these specimens fail, the balance of the heat shall be accepted subject to final inspection for surface, section and finish. If any of these specimens fail, the entire heat shall be rejected.

302. Elongation and Permanent Set

(a) One of the 3 test specimens shall be given a sufficient number of blows to determine, for information only, the elongation reported inch by inch over the entire 6 in. gaged. No elongation readings will be taken between blows.

(b) For information only, the permanent set measured by middle ordinate in inches in a length of 3 ft. shall be recorded after the first blow on all test specimens.

303. Interior Condition

(a) A test piece representing the top end of the top rail of each ingot of each heat rolled, which has passed the drop test requirements of Section 301 shall be nicked and broken. If the fracture on any test specimen exhibits seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine grained structure, the top rail represented shall be classed as an "X-Rayl."

(b) When specified by the purchaser progressive all-ingot nick-and-break testing with elimination of X-Rayls shall be performed as follows:

A test piece representing the top end of the top rail from each ingot of each heat rolled, which has passed the requirements of Section 301, shall be nicked and broken to determine whether the interior metal is sound. If an interior defect shows on the fracture, the top end of the top rail shall be nicked and broken back. If a fracture free from interior defect is reached at a point permitting the rail to be finished to an acceptable length, the rail and the following rails of the ingot shall be accepted. If not, the rail shall be rejected and a test piece cut from its bottom end to represent the second rail of the ingot. The second and succeeding rails shall be tested in the same manner.

The nick-and-break tests on the top end of the rails shall be made at increments optional with the manufacturer and if necessary, in order to obtain a fracture free from interior defects, the tests shall be carried to the point where the finished rail will be of minimum acceptable length.

An interior defect is interpreted to mean seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine-grained structure made visible by the destruction tests.

Short rails produced under this procedure shall be excluded from consideration in the 11 percent limitation of Section 402.

304. Classification

No. 1 Rails.—No. 1 rails shall be free from injurious defects and flaws of all kinds.

X-Rayls.—Rails as described in Section 303 (a).

No. 2 Rails.—Rails which conform to the following requirements will be accepted as No. 2 rails.

(a) Rails which do not contain surface imperfections in such number or of such character as will in the judgment of the inspector render them unfit for recognized uses.

(b) Rails arriving at the straightening presses with sharp kinks or greater camber than that indicated by a middle ordinate of 6 in. in 39 ft.

(c) Rails that are not hot stamped.

IV DETAILS OF MANUFACTURE

401. Discard

Sufficient discard shall be taken from the ingot to insure freedom from injurious segregation and pipe.

402. Lengths

Standard length of rails shall be 39 ft. at a temperature of 60 deg. F. Eleven percent of the entire order will be accepted in shorter lengths varying by 1 ft. from 38 ft. to 25 ft. A variation of $\frac{3}{8}$ in. from the specified length will be allowed, except that on 15 percent of the order a variation of $\frac{7}{16}$ in. will be allowed.

403. Section

Section of rails shall conform as accurately as possible to the templets or drawings furnished by the purchaser. A variation of $\frac{1}{64}$ in. less or $\frac{1}{32}$ in. greater than the specified height will be permitted. A variation of $\frac{1}{16}$ in. in the width of either flange will be permitted, but the variation in total width of base must not exceed $\frac{1}{16}$ in. No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fishing templet approved by the purchaser may stand out not to exceed $\frac{1}{16}$ in. laterally.

404. Weight

A variation of $\frac{1}{2}$ of 1 percent from the calculated weight of section as applied to the entire order will be allowed.

405. Drilling

Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser. A variation of $\frac{1}{32}$ in. in the size and location of bolt holes will be allowed.

406. Finishing

(a) All rails shall be smooth on the heads, straight in line and without twists, waves, or kinks. The support for rails in the straightening presses shall have flat surfaces and be free from hollow places, bends or crooks, and shall be spaced approximately 60 in. Auxiliary supports at less than 60 in. may be used for straightening ends of rails. When placed head up on a horizontal surface, rails that are slightly higher at the ends than the middle will be accepted, provided they contain a uniform sweep, the middle ordinate

of which does not exceed 1¼ in. in 39 ft. They shall be sawed square at the ends, a variation of not more than 3/32 in. (3/64 in. for 140-lb. rail and over) being allowed and burrs shall be entirely removed.

(b) Rails presented for inspection which do not conform to the requirements of Section 405 or Section 406 (a) may be reconditioned by the mill, provided they can be made to fully meet the requirements.

(c) When any finished rail shows conditions as described in Section 303 (a) at either end or at any drilled hole it shall be cut or broken back to sound metal and accepted as a No. 1 or No. 2 short rail, subject to the requirements of Sections 304 and 402. If cut back, a fracture specimen shall be furnished the inspector to determine the interior condition.

407. Branding

Brands that may be read as long as the rails are in service shall be rolled on the side of the web of each rail in accordance with the following requirements:

(a) The data and order of arrangement of the branding shall be as shown in the following typical brand, the design of letters and numerals to be optional with manufacturer.

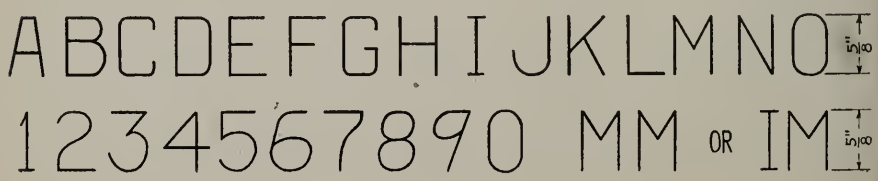
11228	RE	CC	Inland	1945	|||||||
(Weight or Sec. No.)	(Type)	(Control Cooled)	(Mill Brand)	(Year Rolled)	(Month Rolled)

(b) The heat number, the rail letter, and the ingot number shall be hot stamped in the web of each rail where it will not be covered by the joint bars. It is desired that the ingot number shall be in the order as cast. The data used in stamping and arrangement thereof shall be as shown in the following typical stamping.

6 3 3 4 5 A B C D E F G H 17

(Heat Number) (Rail letter) (Ingot No.)

(c) The top rails shall normally be lettered "A" and succeeding ones "B", "C", "D", "E", etc., consecutively, but in case top discard is greater than normal, the rail lettering shall conform to the amount of discard, the top rail becoming "B", or other succeeding letter to suit the condition. Design and size of letters and numerals to be used in stamping shall be as here shown:



408. Control Cooling

(a) All rails shall be cooled in the regular way on hot beds or runways until the temperature is between 1000 deg. and 725 deg. F., then charged immediately into the containers.

(b) The temperature of the rails before charging shall be determined with a reliable pyrometer at the top of the rail head at least 12 in. from the end.

(c) The handling of rails between the hot bed and the container and during subsequent removal therefrom shall be carefully conducted to avoid bending and to minimize cold straightening.

(d) The cover shall be placed on the container immediately after completion of the charge and shall remain in place for at least 10 hr. After the removal or raising of the lid of the container no rails shall be removed until the temperature of the top layer of rails has fallen to 300 deg. F. or lower.

(e) The temperature between an outside rail and the adjacent rail in the bottom tier of the container, at a location not less than 12 in., nor more than 36 in., from the rail end, shall be recorded or indicated with reliable equipment. This temperature shall normally be the control for judging rate of cooling.

(f) The container shall be so protected and insulated that the control temperature shall not drop below 300 deg. F. in 7 hr. for rails 100 lb. per yard in weight, or heavier, from the time that the bottom tier is placed in the container, and 5 hr. for rails of less than 100 lb. per yd. in weight. If for unavoidable mill conditions, this time temperature cycle is not met, the rails shall be considered control cooled provided the temperature at a location not less than 12 in. from the end of a rail in the middle tier does not drop below 300 deg. F. in less than 15 hr.

(g) The purchaser shall be furnished a complete record of the process for each container of rails in accordance with AREA Manual Form 401–D.

(h) The letters CC in all brandings shall be removed from all rails failing to meet the above requirements of Section 408.

(i) Rails may be hot stamped in the web ahead of the heat number with the letters CH for control cooled end hardened rails when specified by the purchaser.

409. Classification Markings

(a) Rails accepted as No. 2 rails shall have the ends painted white and shall be stamped with the figure 2 on both end faces.

(b) Rails accepted as "X-Rayls" shall have the ends painted brown and shall be stamped with the letter "X" on both end faces.

(c) "A" rails shall have both ends painted yellow.

(d) No. 1 rails less than 39 ft. long shall have both ends painted green.

(e) All rails of a heat in which the carbon content is in the upper five points of the carbon percentage of the specified range shall have both ends painted blue.

Individual rails shall be painted only one color, according to the order of precedence listed above.

410. Loading

Rails shall be carefully handled in such manner as to avoid injury and shall be loaded as follows:

(a) No. 1 low carbon rails shall be loaded in separate cars.

(b) No. 1 high carbon rails shall be loaded in separate cars.

(c) No. 2 rails shall be loaded in separate cars.

(d) "X-Rayls" shall be loaded in separate cars.
(e) No. 1 "A" rails shall be loaded in separate cars.
(f) No. 1 short rails shall be loaded in separate cars.

No subdivision by classification markings other than listed above is necessary for separate loading.

411. Mill Practices

The entire process of manufacture shall be in accordance with the best current state of the art. It is expected that thoroughly deoxidized steel will be furnished, and that in every stage of manufacture strict adherence to the standards of the best practice of the individual mill will be observed.

412. Acceptance and Payment

(a) In order to be accepted the rails offered must fulfill all the requirements of this specification.

(b) No. 2 rails to the extent of 8 percent of the whole order will be accepted.

(c) Rails accepted will be paid for according to actual weight subject to the limitation of Section 404.

Report on Assignment 3

Rail Failure Statistics

W. C. Barnes (chairman, subcommittee), W. H. Penfield, C. B. Bronson.

These rail failure statistics have been prepared in the new form that was initiated last year which places special emphasis on the performance of control cooled rail, as rail laid by that process is now predominantly purchased. Such data covering rail made by all processes as are necessary to provide a continuing record of the condition of track and afford a basis for comparison are also included.

These statistics are based on reports from such roads as could furnish complete information on form 402–C, revised 1944, with the exception of Table 1 and Fig. 1 which present data from such roads as could report on form 402–L, issued 1944.

Table 1 lists the transverse fissured rails reported as occurring each year from 1935 to 1944, inclusive, service and detected separately, in rails of all ages, made by all processes, segregated as to roads. In this table a zero indicates a report of no fissure failures, while a dash indicates no report received for that year. Because of the lack of information as to the track miles of rail of all ages reported on by each road, this table should be used for comparisons of failures on individual roads from year to year, rather than for comparisons of failures as between different roads. For a comparison between roads the reader is referred to Table 4, which covers control cooled rail only and in which the track miles are given for each road.

The reported fissure failures in 1944 appear as 6927 service and 31,781 detected, or a total of 38,708 service plus detected. Despite the heavy traffic in 1944, the transverse fissure failures in 1944 are shown to be considerably less than those for 1943, the latter being 7795 service and 36,071 detected, or a total of 43,866 service plus detected, which is a reduction of 868 service failures coincident with a reduction of 4290 detected failures.

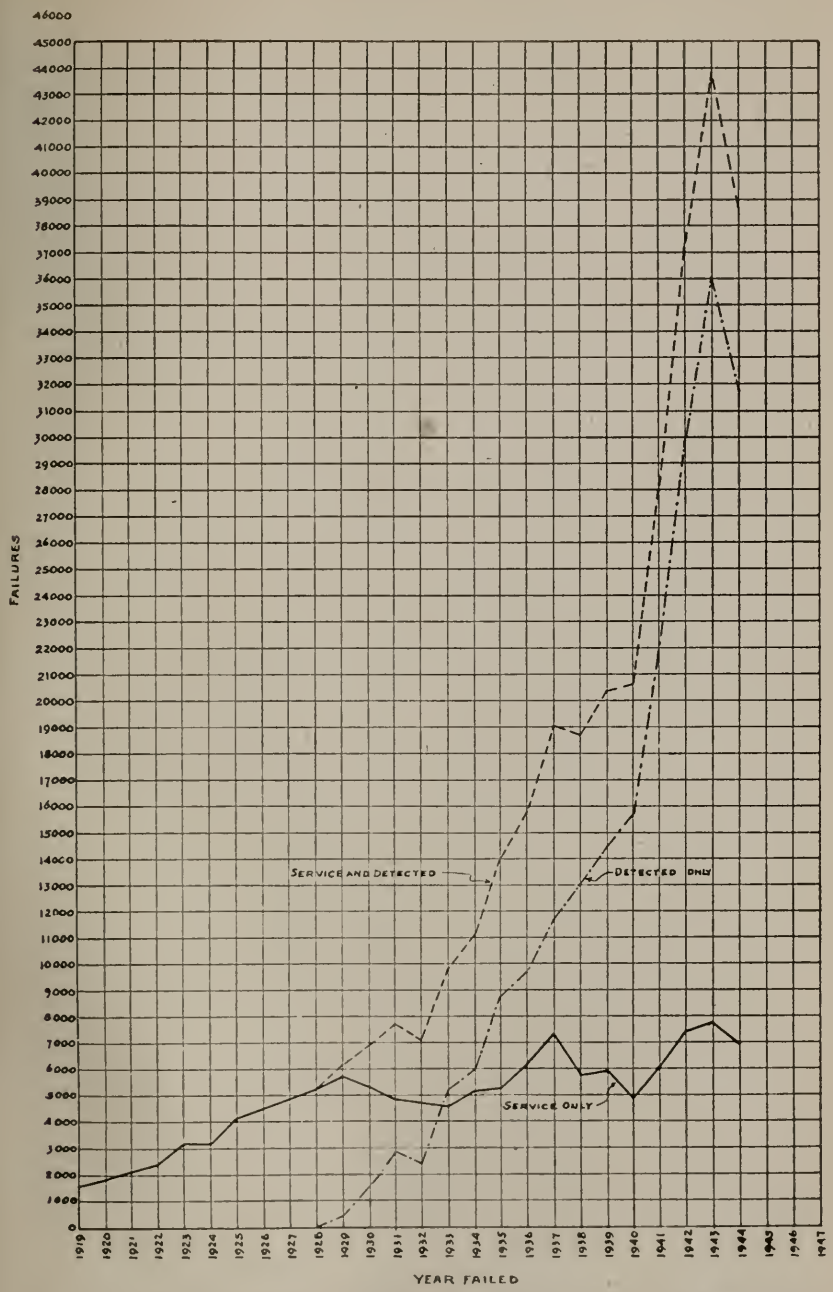


Fig. 1.—Total Transverse Fissured Rails Reported Each Year. Rails Made by All Processes Included. 1930 Includes 11 Months Only.

TABLE 1.—TRANSVERSE FISSURED RAILS BY RAILROAD AND BY YEAR FAILED—ALL ROLLINGS, OF ALL PROCESSES

Yr. Failed	SERVICE FAILURES											DETECTED FAILURES										
	1935	1936	1937	1938	1939	1940	1941	1941	1943	1944	Total	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	Total
AT&SF	35	46	92	43	85	111	140	341	455	307	1, 655	121	59	247	194	326	377	275	566	831	647	3, 643
ACL	48	62	102	66	67	114	121	250	218	267	1, 315	0	159	180	251	141	118	288	809	1, 220	870	4, 036
Ban. & Aroos.	0	0	0	0	0	0	0	3	3	4	10	0	0	0	0	0	0	0	0	0	0	0
B&OCT										2	2										0	0
B&LE										10	10										0	0
B&M	18	12	14	28	25	11	20	20	42	64	254	0	241	207	45	706	927	785	661	884	276	4, 732
B&O	356	325	431	382	282	341	459	588	425	367	3, 956	618	630	652	807	431	609	797	1, 421	1, 269	780	8, 014
CP	121	134	138	114	164	225	501	425	381	238	2, 441	899	999	1, 501	1, 239	1, 780	2, 011	3, 813	5, 201	5, 964	5, 064	28, 471
C. of Ga.	54	64	55	59	70	77	109	62	77	61	688	101	96	119	110	91	130	248	223	407	179	1, 704
C.ofN.J.	58	110	112	90	69	87	81	77	77	71	832	0	0	0	0	0	0	0	0	0	0	0
C&EI	14	18	22	23	15	15	23	31	48	51	260	65	29	65	77	89	96	120	138	271	352	1, 302
C&O	300	227	310	187	145	93	100	123	107	71	1, 663	1, 262	1, 392	891	923	786	533	539	417	540	393	7, 676
C&NW	69	68	41	38	47	62	78	162	168	160	893	155	355	317	294	465	631	820	1, 463	1, 495	1, 578	7, 573
CB&Q	214	164	167	134	151	161	199	272	323	287	2, 072	315	447	413	602	662	668	747	774	1, 733	1, 245	7, 606
CI&L										12	12										19	19
CMSt.P &P	71	74	53	46	45	73	77	119	136	136	830	247	197	357	288	285	311	340	684	468	1, 062	4, 239
CRI&P	97	135	121	98	74	91	115	158	247	183	1, 319	62	132	344	366	336	269	136	390	605	645	3, 285
C&S										26	26										28	28
D&H										67	67										192	192
DL&W	76	90	75	72	72	56	85	96	23	27	672	244	229	454	461	400	140	0	1, 089	369	333	3, 719
D& RGW										203	203										114	114
Erie	171	167	229	123	133	110	129	210	207	177	1, 656	165	0	166	264	350	238	599	405	1, 133	971	4, 291
Fla. EC										152	152										367	367
GN	179	246	276	215	246	232	224	225	261	243	2, 347	114	88	69	92	142	171	150	258	366	430	1, 880
GM&O	28	45	76	55	83	62	85	57	48	29	568	0	0	0	0	0	0	0	28	298	306	632
GTW										43	43										112	112
IC(Sys)	364	467	540	515	520	474	556	699	534	311	4, 980	284	314	447	557	596	727	471	1, 483	2, 000	1, 925	8, 804
KCS										14	14										178	178
L&HR	0	1	5	6	8	11	2	10	1	8	52	0	0	0	0	0	22	0	24	0	24	70
L&NE	0	0	6	1	5	4	1	8	3	5	33	0	0	24	0	0	26	0	27	12	4	93
LV	31	22	28	52	41	30	30	79	41	33	387	0	140	0	0	218	6	150	171	128	189	1, 002
L&N	181	253	229	178	178	130	139	202	217	160	1, 867	341	488	577	530	408	530	561	925	800	747	5, 907
Me. Cen.										12	12										21	21
MSt.P & SSM										13	13										39	39
MKT	33	39	30	35	80	66	110	81	131	92	697	74	77	167	169	61	132	4	455	249	515	1, 903
Mo.Pac. R.R.									228	*	228									1, 328	*	1, 328
Mo.Pac. Lines									68	25	93									502	728	1, 230

TABLE 1.—Continued

Yr. Failed	SERVICE FAILURES											DETECTED FAILURES										
	1935	1936	1937	1938	1939	1940	1941	1941	1943	1944	Total	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	Total
NC& StL	19	50	36	19	30	35	48	39	57	58	391	45	17	42	70	42	115	110	126	218	172	957
NYC (Sy.)**	321	383	367	389	433	357	462	617	652	406	4387	191	322	322	430	562	352	428	623	844	559	4, 633
NYC& St.L									192	86	278									392	318	710
NYC Trans.										3	3										0	0
NYNH &H	34	37	48	39	31	28	30	34	24	21	326	82	60	101	92	110	58	98	121	268	136	1, 126
NYO &W	34	21	37	55	33	20	20	32	16	62	330	0	0	0	0	0	0	0	0	0	53	53
N&W	23	38	36	22	21	10	7	9	2	3	171	0	0	84	45	44	53	63	49	34	40	412
NP†	168	171	259	213	185	147	217	241	317	310	2, 228	324	173	292	246	310	227	326	470	589	440	3, 397
PRR	414	544	672	513	442	323	425	440	517	365	4, 655	1, 073	690	757	857	920	1, 158	1, 048	858	799	1, 026	9, 186
PM	7	7	8	4	2	2	0	9	15	4	58	57	58	137	34	27	20	14	111	124	87	669
P&LE										4	4										4	4
Rdg.	166	162	186	164	191	148	283	267	172	173	1, 912	0	0	0	0	0	0	0	0	0	367	367
RF&P	4	2	4	3	2	5	16	27	28	31	122	67	44	53	52	61	37	186	168	238	228	1, 134
Rutland	1	1	1	1	2	2	2	1	1	3	15	3	0	0	0	0	0	0	8	0	0	11
S.P.(Pac. Lines)	200	324	481	394	590	347	356	452	426	445	4, 015	455	767	629	637	477	709	1, 424	1, 610	2, 002	1, 536	10, 246
Sou(Sy.)	261	368	504	256	226	258	256	337	311	278	3, 055	0	0	0	1, 263	1, 061	1, 101	2, 151	2, 454	3, 541	2, 360	13, 931
St.LSF										111	111										573	573
T&NO										239	239										795	795
Tex. & Pac.							98	93	160	128	479							760	758	839	869	3, 226
UP(Sy.)	1, 003	1, 176	1, 443	923	1, 033	481	395	447	389	226	7, 516	1, 361	1, 437	1, 996	2, 032	2, 525	3, 022	4, 226	4, 479	3, 045	1, 587	25, 710
Virginian	30	23	36	34	39	30	27	16	12	11	258	0	0	0	0	0	126	90	173	114	114	617
W.Md.	87	116	70	133	50	53	43	48	35	26	661	0	0	86	0	72	82	148	228	152	184	952
W&LE										3	3										0	0
All Roads	5, 290	6, 192	7, 340	5, 722	5, 915	4, 882	6, 069	7, 407	7, 795	6, 927	63, 539	8, 725	9, 640	11, 696	13, 027	14, 484	15, 732	21, 915	29, 848	36, 071	31, 781	192, 919

*Report received covers CC & BR rail failures only.
**Including IHB failures.
†Including L.I. R.R. & P-R.S.L.

Table 2.—Tons and Track Miles of Each Year's Rollings, 1934–1943, Incl., Included in These Statistics

All Roads and All Processes from All Mills

Year Rolled	*Tons*	*Track Miles*
1934	460,015	2,498.94
1935	420,173	2,340.44
1936	811,090	4,431.44
1937	943,329	5,170.09
1938	460,638	2,598.16
1939	830,498	4,448.41
1940	906,935	4,945.70
1941	1,043,388	5,612.78
1942	1,089,094	5,883.24
1943	1,163,760	6,344.76
	8,128,920	44,273.96

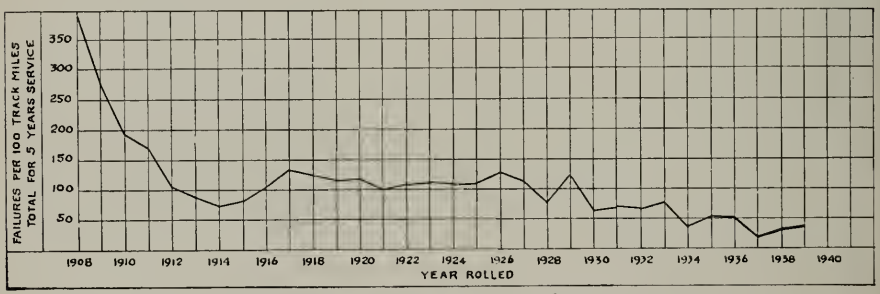


Fig. 2.—Service and Detected Rail Failures in the United States and Canada.

It would appear that this reduction is probably due to the increased proportion of control cooled rail in use in heavy traffic main line, although there is a possibility that the intensive detector car testing in recent years is gaining control of the failure rate. The failures which were reported as occurring in 1919 to 1944, reproduced from Table 1 of this and previous reports, are shown in Fig. 1.

Table 2 lists the tons and track miles of each year's rollings, 1934–1943, inclusive, which are included in these statistics. They include rail made by all processes.

Table 3 shows the combined service and detected failures of all types per 100 average track miles, accumulated in ten to one year's service of rails rolled in 1933 to 1943, reported by all except one road for which complete data are lacking, in rails of all processes from all mills. Prior to last year's report this table included the failure rates for five to one year's service only, but starting last year this table is being expanded to show ten to one year's service, for the purpose of affording a more adequate idea of the performance of the rail.

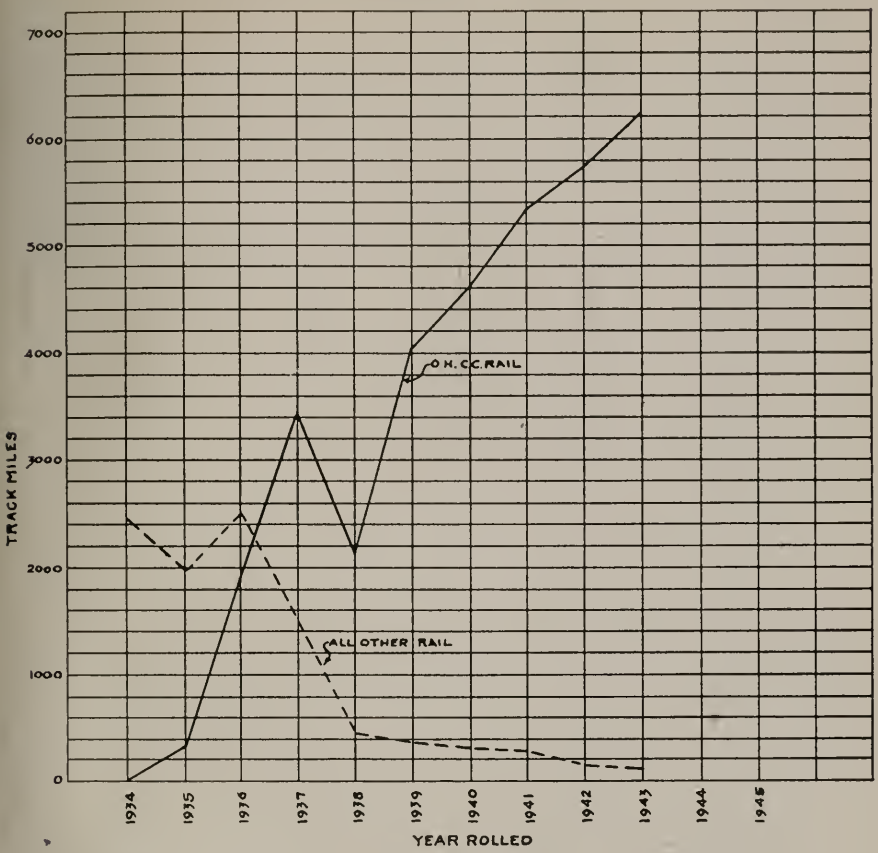


Fig. 3.—Chart Showing Rapid Adoption of O.H. Control Cooled Rail.

Fig. 2 is a continuation of the chart previously presented, showing the rates of failure in various rollings accumulated in five years' service. A plotting of the failure rates for ten years' service will be added as soon as data have been accumulated for that purpose.

Fig. 3 is a chart showing the rapid increase in track miles of control cooled rail of rollings 1934–1943, inclusive, as reported by all roads. It also shows the declining use of rail made by all other processes.

Table 4 shows separately the track miles and 1944 failures of all types in open hearth control cooled rail, Brunorized rail and intermediate manganese control cooled rail by roads and by mills, the total track miles reported of open hearth control cooled rail being 33,829, of Brunorized rail 828 and of intermediate manganese control cooled rail 74. Table 4 as presented this year embodies some changes in the data presented last year to agree with corrected reports received from some roads.

Table 5 presents the accumulated failures in rollings 1934–1943 from the date rolled to December 31, 1944, by type of failure and by mill, open hearth control cooled and intermediate manganese control cooled rail shown separately. It also shows the track miles and failure rates of all types of failure by mills. It wil be noted that no transverse

TABLE 3.—SERVICE AND DETECTED FAILURES OF ALL TYPES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1944 PER 100 AVERAGE TRACK MILES, ON ALL REPORTING ROADS, IN ALL ROLLINGS BY ALL PROCESSES FROM ALL MILLS

Year Rolled	Years Service									
	1	2	3	4	5	6	7	8	9	10
1933	6.2	11.7	25.6	52.4	73.5	91.6	122.9	174.9	246.3	332.0
1934	4.6	13.6	19.3	25.9	35.8	53.1	80.1	116.7	175.9	233.1
1935	4.2	9.6	16.3	32.3	51.0	85.8	129.0	213.5	326.9	
1936	4.2	7.3	18.1	30.6	50.7	90.7	144.7	228.7		
1937	3.3	5.8	11.3	15.9	23.9	39.3	67.8			
1938	2.2	5.2	10.4	20.7	32.6	48.7				
1939	2.6	5.0	9.9	20.8	36.8					
1940	1.3	3.1	8.7	18.3						
1941	1.5	4.0	9.0							
1942	2.2	6.1								
1943	3.6									

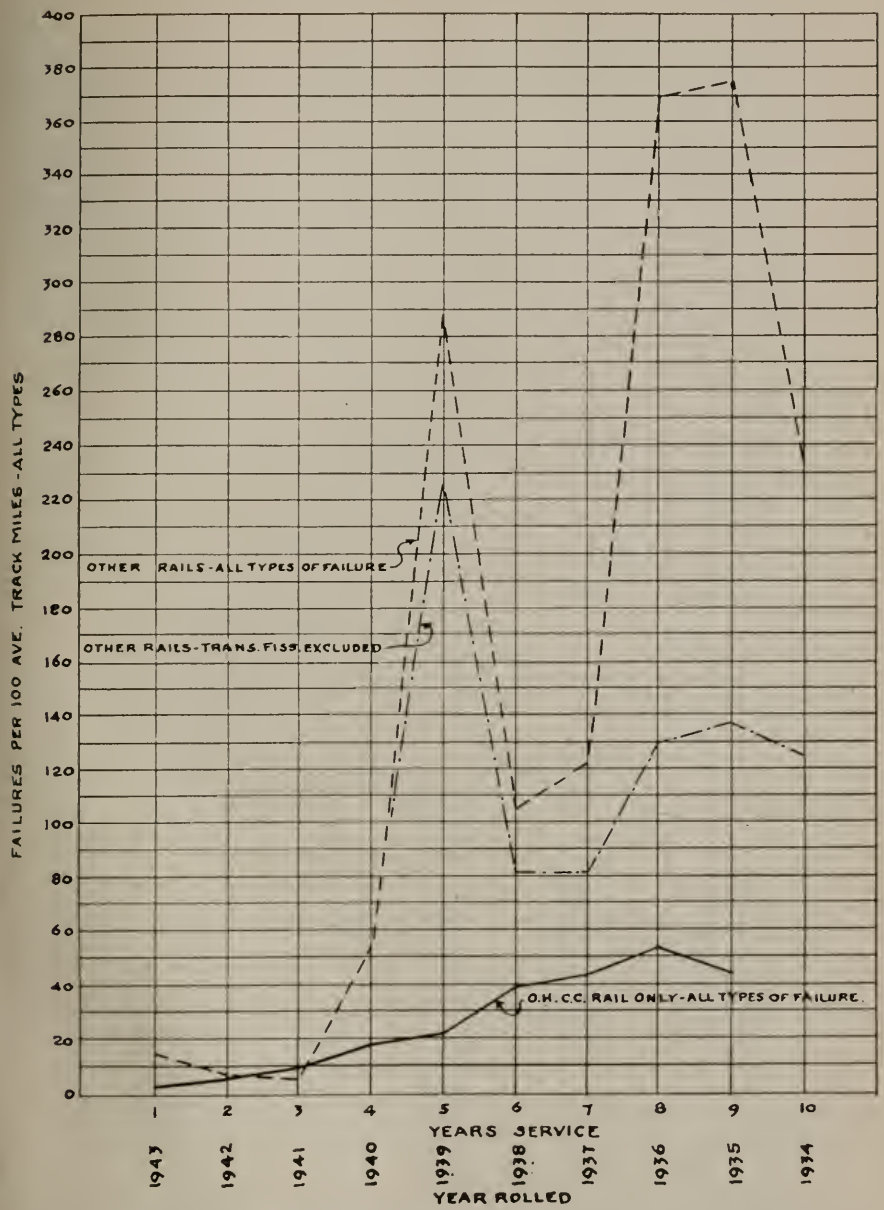


Fig. 4.—Control Cooled and Other Process Rail Failures to Dec. 31, 1944, All Types, Service and Detected, Per 100 Ave. Track Miles, One to Ten Years Service. (Brunorized Rail Not Included.)

Table 4.—Control Cooled & Brunorized Contract Rail

Track Miles and Failures, All Types, in Rollings 1934 to 1943, Incl.

ROAD	BRUNORIZED		OH CONTROL COOLED											
	Trk. Mls	1944 Fail-	Track Miles											1944 Fail-
	Gary	ures	Alg.	Carn.	Colo.	Dom.	Tenn.	Gary	Inld.	Lacka.	Md.	Stltn.	Total	ures
AT&SF					2, 031			540	105			74	2, 750	98
ACL							180						180	5
B&A										111			111	
B&O				324				268	14	54		171	831	63
B&OCT								4	13				17	
B&LE				119									119	1
B&M				89						108		124	321	69
CP			2, 079			220				57			2, 356	169
C of Ga.							185						185	8
C of NJ												130	130	
C&EI								106	16				122	4
C&O				56				695	415			156	1, 322	140
C&NW	110	28						284	69				353	4
CB&Q	136	6			550			399	170				1, 119	18
CCC&StL	16							463	8	24			495	5
CI&L								35					35	
CMStP&P	255	10						525	243				768	7
CRI&P	60				297			697	254				1, 248	19
D&H												264	264	29
DL&W				51						247		12	310	12
D&RGW					371								371	10
Erie				510				198	59	125			892	34
Fla. FC				11			77						88	3
GN	132	42						295	106	168			569	34
GTW								103	21				124	13
IC	32	9					333	649	294				1, 276	25
IHB									12				12	
KCS	27							158	32			10	200	6
L&H												14	14	
L&NE				10								22	32	
LV										114			114	2
L&N							1, 150	53					1, 203	113
Me. Cent.										39			39	2
Mich. Cent	15		175					159					334	2
MKT					32			107	4				143	5
MP RR					714		146	308	223				1, 391	53
MP Lines				15	113		109						237	5
NC&StL							199						199	58
NYC—East				4				27		621			652	20
NYC—West	26	3						287	94	145			526	5

TABLE 4.—Continued

ROAD	BRUNORIZED		OH CONTROL COOLED											
	Trk. Mls	1944 Fail-	Track Miles											1944 Fail-
	Gary	ures	Alg.	Carn.	Colo.	Dom.	Tenn.	Gary	Inld.	Lacka.	Md.	Stltn.	Total	ures
NYC&StL				27				243	70	63			403	41
NYNH&H				248								217	465	61
N&W				592								197	789	85
NP								636	24	277			937	21
PRR				739	157			500	112	40		581	2, 129	626
PM			78	97					71	32			278	7
P&LE				90									90	1
Reading												81	81	4
RF&P												73	73	24
Rutland										3			3	3
St.LSF							503						503	39
SP					1, 162		685					467	2, 314	422
Sou. Ry							901	34				252	1, 187	68
T&NO					244							170	414	5
T&P					155		287						442	
UP	19	1			917			781	153				1, 851	107
Va				74						5		154	233	38
W&LE				185									185	22
Total	828	99	2, 332	3, 241	6, 743	220	4, 755	8, 554	2, 582	2, 233		3, 169	33, 829	2, 615

IM CONTROL COOLED

D&H												58	58	8
D&RGW					16								16	52
Total					16							58	74	60

TABLE 5.—ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1934 TO 1943, INCLUSIVE, FROM DATE ROLLED TO DECEMBER 31, 1944, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE

OH Control Cooled Rail Only

Mill	Accumulated Failures to Dec. 31, 1944							Ave. Track Miles	Track Mile Years	Failures per 100 Track Mile Years
	Transv. Fiss.	Comp. Fiss. Det. Frac. from Eng. Burns, Shell	VSH HSH Other Head	Broken	Web†	Base	All Types			
Algoma	1**	1	144	26	98	109	379	2,332	8,712	4.35
Carnegie (ET)	0	139	139	144	930	5	1,357	3,226	11,601	11.70
Colorado	0	76	439	66	188	12	781	6,630	23,143	3.69
Dominion			2		6		8	220	1,529	0.52
Gary	6*	102	222	104	91	44	569	8,554	27,517	2.07
Inland	7**	70	108	78	73	35	371	2,582	11,726	3.16
Lackawanna		23	51	40	151	46	311	2,233	8,413	3.70
Maryland										
Steelton	18**	205	201	73	291	4	792	3,169	12,344	6.42
Tennessee		34	674	254	439	77	1,478	4,646	18,522	7.98
All Mills	32	650	1,980	785	2,267	332	6,046	33,592	123,507	4.90
Failures per 100 Tr. Mi. Yrs.	0.03	0.53	1.60	0.64	1.84	0.27	4.90			

IM Control Cooled Rail Only

Colorado		50	10	4			64	16	64	100.00
Steelton			2	2	11		15	58	426	3.52
All Mills		50	12	6	11		79	74	490	16.12
Failures per 100 Tr. Mi. Yrs.		10.20	2.45	1.22	2.24		16.12			

* One developed from porosities and 5 resulted from use of unsuitable cooling box covers.
** Developed from inclusions or from porosities.
† Bolt hole breaks, fillet cracks and head and web separations also included.

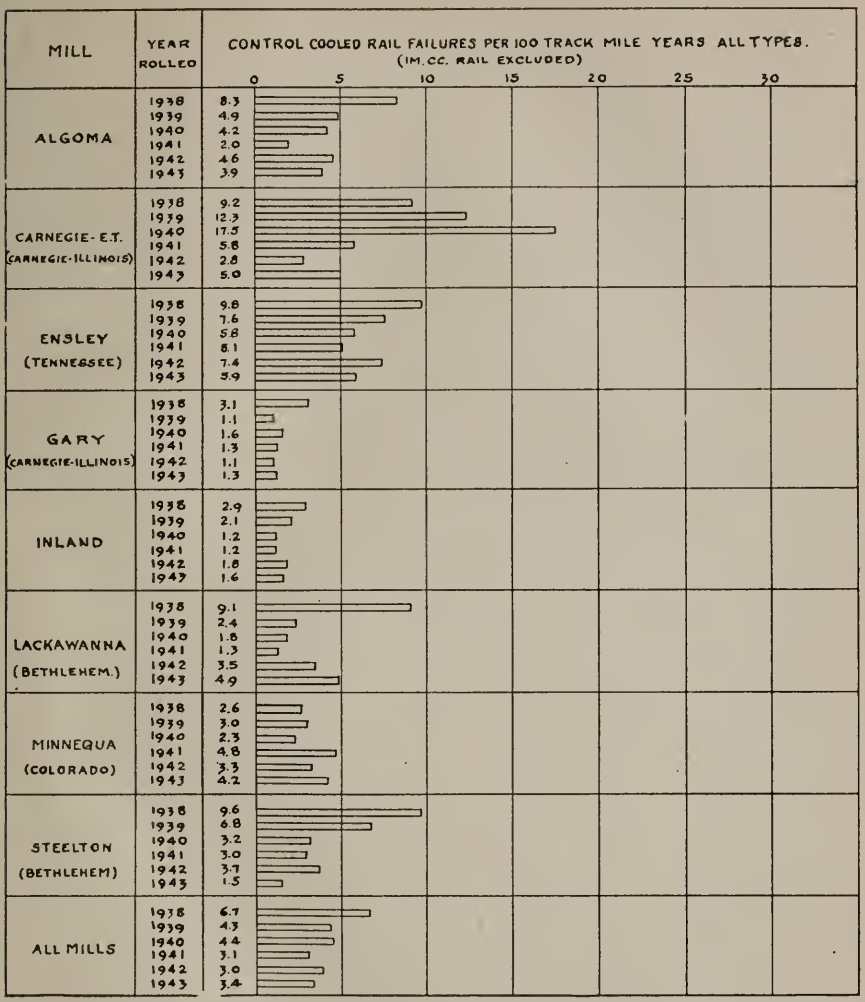


Fig. 5.—Control Cooled Rail Failure Rates From Date Rolled to Dec. 31, 1944, by Mills. (Service and Detected Failures of All Types Included.)

fissure failures have been reported as originating in shatter cracks except five which resulted from the use of unsuitable cooling box covers. A rather wide variation in other types of failure as between mills is reported. This table includes data from all except one road which could not furnish complete data, and is based on reports on form 402-C.

Table 6 shows the transverse fissure failures accumulated to September, 1945, in control cooled and Brunorized rail which have been verified by laboratory investigation, the data being segregated by the road, mill and the year rolled. It will be noted that Table 6 includes failures to September 1945 from information furnished by Professor Cramer of the University of Illinois, whereas the data on Table 5 are accumulated to December 31, 1944.

TABLE 6.—ACCUMULATED TRANSVERSE FISSURE FAILURES BY ROAD, MILL AND YEAR ROLLED TO SEPTEMBER 1945
OH CONTROL COOLED AND BRUNORIZED ONLY SHOWN SEPARATELY

OH Control Cooled Only (Includes CC Failures Verified by Laboratory Investigation Only)

Roads	*Mills*	*1931*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*Total*
PM	Algoma										1						1
NY NH & H	Carnegie (ET)							1									1
C&O	Gary						1										1
C&NW	Gary						2(a)										2
CB&Q	Gary						3(a)										3
C&O	Inland					1	5	1				1					8
UP	Inland									3	1						4
C&O	Steelton							1	1								2
D&HR	Steelton								1	1							2
N&W	Steelton									1	1						2
NY NH & H	Steelton							2			1		1				4
PRR	Steelton						2										2
RF&P	Steelton										1						1
SP	Steelton						7	1									8
	Total					1	20	6	2	5	5	1	1				41
	Algoma	*	*								1						1
	Carnegie	*	*	*	*			1									1
	Dominion																0
	Ensley	*	*	*	*	*											0
	Gary	*	*	*	*		6										6
	Inland	*	*	*	*	1	5	1		3	1	1					12
	Lackawanna	*	*	*	*												0
	Maryland	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0
	Minnequa	*	*	*	*	*											0
	Steelton	*	*	*	*		9	4	2	2	3		1				21
All Roads	All Mills					1	20	6	2	5	5	1	1				41

Note: Laboratory investigation showed that all of the above transverse fissures, except those marked (a), developed from inclusions or porosities. The 5 Gary failures resulted from use of unsuitable cooling box covers.
*No CC rail rolled.

Brunorized Only

C&NW	Gary						9	26									35
CB&Q	Gary								2								2
GN	Gary								2								2
IC	Gary							69									69
NYC Sys	Gary							3									3
	Total						9	98	4								111

Note: Rolling of Brunorized old process rail started October 1936. Process revised April 27, 1938. Rolling discontinued November 18, 1941. Not all of the Brunorized failures were verified as they were all in old process rail.

TABLE 7.—COMPARISON OF RAIL FAILURES OF ALL TYPES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1944 PER 100 AVERAGE TRACK MILES OF CONTROL COOLED, BRUNORIZED AND "OTHER" PROCESS RAILS ROLLED IN 1934 TO 1943, INCLUSIVE, SERVICE AND DETECTED

YEAR ROLLED	*1943*	*1942*	*1941*	*1940*	*1939*	*1938*	*1937*	*1936*	*1935*	*1934*
Years Service	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Control cooled rail (Excl. IM-CC Rail)	3.4	6.0	9.3	17.5	21.4	39.6	44.1	52.7	44.1	----------
Brunorized rail	----------	----------	1.4	4.0	1.5	46.0	81.4*	149.2*	----------	----------
"Other" process rail	14.7	7.1	6.2	54.3	289.5	105.0	123.5	369.6	374.8	233.1
Rail Made by All Processes	3.6	6.1	9.0	18.3	36.8	48.7	67.8	228.7	326.8	233.1

Note: *Old Process Brunorized rail only. "Other" Process rail includes Bessemer, plain open hearth, medium manganese, control cooled medium manganese, etc. and excludes control cooled OH and Brunorized.

Dates on which rolling of contract rail started

Control Cooled

Dominion .....Jan. 1931
Algoma .....Dec. 1933
Steelton .....Mar. 1935
Inland .....Apr. 1935
Lackawanna .....May 1935
Carnegie .....Oct. 1935
Colorado .....Jan. 1936
Ensley .....Feb. 1936
Gary .....Apr. 1936

Brunorized

Gary—old process .....Oct. 1936
revised process .....Apr. 27, 1938
rolling discontinued .....Nov. 18, 1941

Table 7 is a comparison of rail failures of all types accumulated from the date rolled to December 31, 1944 per 100 average track miles separately of control cooled, Brunorized and "other" process rail rolled in 1934–1943, inclusive, service and detected. This table agrees with Table 3 and, as in that case, includes reports from all but one reporting road.

The data for control cooled rail excluding intermediate manganese control cooled rail and "other" process rail from Table 7 is shown in Fig. 4 in graphic form with the addition of a curve showing the failure rates in "other" process rail of all types after transverse fissures have been eliminated.

Fig. 5 is a mill rating chart showing the failure rates per 100 track mile-years in open hearth control cooled rail only, all types, by mills, in rollings 1938–1943, inclusive, from the date rolled to December 31, 1944. In future reports the data will be extended until ten years' rollings are included. The rates of failure for rail from Dominion mill are not presented for the reason that insufficient tonnages for the purpose were reported by roads which could furnish complete information. Maryland mill is not shown as it rolled no control cooled rail during the period covered.

Report on Assignment 6

Continuous Welding of Rail

Collaborating with Committee 5

I. H. Schram (chairman, subcommittee), S. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, C. B. Bryant, C. J. Code, P. O. Ferris, G. W. Harris, F. R. Layng, G. M. Magee, C. E. Morgan, L. T. Nuckols, E. E. Oviatt, W. H. Penfield, J. C. Ryan, R. T. Scholes, R. P. Winton.

This is a progress report presented as information.

Data for additional installations included in the report appear on a folded insert, while a complete summary of the installations of continuous welded rail, revised to date, appears on another folded insert. An abbreviated summary appears below. Your committee reports additional failures of continuous welded rail in 13 of the installations.

INSTALLATIONS OF CONTINUOUS WELDED RAIL - SUMMARY TO DATE

Process	Maximum Continuous Lengths Welded Without Intervening Joints Road	Feet	Number of Welded Joints	Weight of Rail Lbs.per Yd.	Bars Applied	Maximum Wheel Load Lbs.	Annual Tonnage	Traffic Pass.	Traffic Frt.	Speed M. P. H.	Date Installed	In Tunnel or Open	Failures
"A" Gas Fusion - - - - -	(M.P.)	3510	180	90	Yes	32,150	2,700,000	Pass.	Frt.	30	1937	Tunnel	None
	(W.P.)	2808	144	90	Yes	32,150	2,700,000	"	"	30	1938	"	"
	(W.P.)	2691	138	90	Yes	32,150	2,700,000	"	"	30	1938	"	"
	(W.P.)	585	31	90	Yes	32,150	2,700,000	"	"	50	1938	"	"
	(W.P.)	1053	54	90	Yes	32,150	2,700,000	"	"	50	1939	"	"
	(C. of Ga.)	2457 (1)	126	90	Yes	32,500	4,500,000	"	"	30	Sept 1930	"	22
	(C. of Ga.)	1283 (1)	66	90	Yes	32,500	4,500,000	"	"	30	Aug. 1930	"	10
			739										32
	(C. of Ga.)	2563 (6)	131	112 RE	Yes	32,500	4,500,000	"	"	30	Apr. 1937	"	19
	(C. of Ga.)	1389 (6)	71	112 RE	Yes	32,500	4,500,000	"	"	30	Apr. 1937	"	12
			202										31
	(C. of Ga.)	2184	110	112 RE	Yes	32,500	10,740,000	"	"	60	Oct. 1937	Open	None
	(G. N.)	1122 (2)	32	131 RE	No	36,000	13,200,000	"	"	60	Dec. 1939	"	"
"B" Gas Fusion - - - - -	(L. & N.)	1636 (3)	82	100 RE	Yes	Not Reported	15,000,000	"	"	60	May 1936	Tunnel	37
	(L. & N.)	1014	52	100 RE	Yes	26,250	8,000,000	"	"	40	May 1936	"	9
	(L. & N.)	2324 (5)	117	101.49	Yes	26,250	6,721,110	"	"	70	Feb. 1939	"	11
	(L. & N.)	1092 (7)	54	101.49	Yes	26,250	7,147,430	"	"	60	Feb. 1939	"	4
	(L. & N.)	747	38	100 RE	Yes	26,250	8,000,000	"	"	40	Apr. 1939	"	5
			343										66
	(Sou. Ry.)	4125	162	100	Yes	31,000	6,000,000		"	20	Sept 1936	Open	28
"C" Thermit (Old Type) -	(Erie)	5616 (8)	168	131 RE	No	36,000	16,500,000		"	40	June 1936	Tunnel	81
	(N. P.)	3783	194	131 RE	No	37,000	7,000,000	"	"	25	July 1936	"	28
	(N. P.)	4017	206	131 RE	No	37,000	7,000,000	"	"	25	Aug. 1936	"	37
			568										146
	(B. & L.E.)	5280	269	131 RE	No	37,900	9,000,000	"	"	55-35	Oct. 1935	Open	43
	(D. & H.)	2994	318	130 RE	No	32,000	4,150,000	"	"	20	Aug. & Sept 1935	"	9
	(D. & H.)	2519	254	131 RE	No	34,425	3,000,000	"	"	30	May 1934	"	1
	(D. & H.)	5963	551	131 RE	No	34,425	9,000,000		"	45	June & Sept 1935	"	44
	(D. & H.)	3089	281	131 RE	No	34,425	5,286,241		"	20	1938	"	3
	(D. & H.)	4054	408	131 RE	No	32,000	3,714,700	"	"	75	May & June 1936	"	8
	(D. & H.)	591	74	131 RE	No	34,425	3,567,000	"	"	20	June 1936	"	None
			2155										108
"C1" Thermit (Type K) - -	(D. & S. L.)	34055 (4)	1052	112 RE	No	36,500	Not Reported	"	"	60	July 1936	Tunnel	59
	(B. & O.)	1365	68	112 RE	No	32,000	10,000,000	"	"	45	July 1939	"	5
	(B. & O.)	2145	108	112 RE	No	32,000	10,000,000	"	"	45	July 1939	"	9
			1288										53
	(G. N.)	5668	290	110 RE	No	35,000	6,042,000	"	"	55	1937	Open	1
	(D. & H.)	7018	1559	131 RE	No	34,425	9,000,000		"	30	1937	Open	8
	(D. & H.)	2519	253	131 RE	No	34,425	3,000,000	"	"	55	Sept 1939	"	None
	(D. & H.)	5566	98	131 RE	No	32,000	5,353,500	"	"	65-55	June - July 1937	"	4
	(D. & H.)	5168	65	131 RE	No	34,425	11,860,000	"	"	60	1937	"	1
	(D. & H.)	4333	53	131 RE	No	32,000	3,567,000	"	"	65	1937	"	None
	(D. & H.)	5273	47	131 RE	No	34,425	16,969,738	"	"	60	1937	"	7
			2075										20
"C2" Thermit (Full Fusion)	(D. & S. L.)	4353	1552	130 PS	No	36,500	10,000,000	"	"	40	Jan. - July 1943	Tunnel	None
	(Erie)	5577	286	131 RE	No	36,000	23,000,000		"	40	Oct. 1943	"	None
			1838										-
"D" Electric Pressure Weld - - - - - - - - - - -	(Erie)	5540	282	131 RE	No	36,000	10,350,000		"	40	Oct. 1939	Tunnel	8
	(D. & H.)	6983	70	131 RE	No	34,425	9,000,000		"	45	June - Sept 1936	Open	2
	(D. & H.)	5953	874	131 RE	No	34,425	9,000,000	"	"	30	1937	"	None
	(D. & H.)	5565	1987	131 RE	No	32,000	5,353,500	"	"	55-35	June - July 1937	"	1
	(D. & H.)	4333	1628	131 RE	No	32,000	3,567,000	"	"	55	1937	"	None
	(D. & H.)	3273	513	131 RE	No	34,425	16,969,738	"	"	60	1937	"	1
	(D. & H.)	3168	1142	131 RE	No	34,425	11,860,409	"	"	60	1937	"	1
	(D. & H.)	1401	1069	131 RE	No	32,000	5,353,500	"	"	65	May 1939	"	None
			7277										5
"E" Gas Pressure Weld (Oxweld) - - - - - - - - -	(C. G. W.)	2640	257	112 RE	No	30,500	8,000,000	"	"	60	May 1939	Open	5
	(C. & I.M.)	953	131	112 RE	No	32,400	7,000,000	"	"	15	July 1939	"	None
			388										5
	(C. of Ga.)	2574	128	118 RE	No	32,500	11,250,000	"	"	30	May 1944	Tunnel	None
	(C. of Ga.)	1287	64	112 RE	No	32,500	11,250,000	"	"	30	May 1944	"	None
			192										-
	(E. J. & E.)	3605	1473	131 RE	No	32,850	15,500,000		"	45	Sept 1943	Open	None
	(E. J. & E.)	3191	346	131 RE	No	32,850	13,400,000		"	45	June 1944	"	None
	(E. J. & E.)	12788	1128	131 RE	No	32,850	13,300,000		"	45	July 1944	"	1
	(E. J. & E.)	11440	1199	131 RE	No	32,850	20,100,000		"	45	Sept 1944	"	1
			4146										2

(1) Removed April 1937; installation renewed with "A" Gas Fusion Weld. (2) Normalized by control cooling.
(3) Removed January 1941. (4) Moffat Tunnel. Removed January and July 1943; installation renewed with "C2" Thermit Full Fusion Weld. (5) Removed February 1943. (6) Removed May 1944; installation renewed with "E" Gas Pressure Weld. (7) Removed January 1944. (8) Removed October 1943; installation renewed with "C2" Thermit Full Fusion Weld.

ADDITIONAL INSTALLATIONS OF CONTINUOUS WELDED RAIL

	Process E - Gas Pressure Weld (Oxweld)						Process C2 - Thermit Full Fusion Weld	
1 Railroad	Central of Georgia Railroad	Central of Georgia Railroad	Elgin, Joliet & Eastern Railway	Elgin, Joliet & Eastern Railway	Elgin, Joliet & Eastern Railway	Elgin, Joliet & Eastern Railway	Erie Railroad	Denver & Salt Lake Railway
2 Location of welded section	24 mi. east of Birmingham, Ala.	24 mi. east of Birmingham, Ala.	Coynes, Ill.	Coynes, Ill.	Normantown, Ill.	Frankfort, Ill.	Otisville, N. Y.	Moffat Tunnel
3 Maximum continuous length welded without intervening joints	2574 ft.	1287 ft.	4205 ft.	3191 ft.	12,782 ft.	11,440 ft.	6,377 ft.	4353 ft.
4 Total length of adjoining welded sections	None	None	5411 ft.	4206 ft.	None	None	None	None
5 Date installed	May 1944	May 1944	Sept. 1943	June 1944	June 1944	Sept. 1944	Oct. 1943	Jan.&July 1943
6 Is traffic one-way or two-way over welded rail?	Two-way	Two-way	One-way	One-way	One-way	One-way	One-way	Two-way
7 Straight-Curve or both	Both	Straight	Both	Straight	Both	Straight	Straight	Straight
8 Maximum degree of curvature	6°	-	2°	-	3°30'	-	-	-
9 Grade (up or down with reference to direction of traffic)	+1.17 westbound	-	+0.4 westbound	+0.4 westbound	+0.4 westbound	+0.4 westbound	+0.18 westbound	+0.9 eastbound
10 Length of rail before welding	39'	39'	39'	39'	39'	39'	39'	39' & 66'
11 Weight of rail	112# RE	112# RE	131# RE	131# RE	131# RE	131# RE	131# RE	130# PS
12 Total joints welded both sides of track(segregated by type of weld)	126	64	1473	346	1122	1199	286	1562
13 Type of weld	Oxweld Pressure Butt Weld 2 Oxy-acetylene	Oxweld Pressure Butt Weld	Gas Pressure Welds 16 Gas Fusion Welds	Gas Pressure Welds 6 Gas Fusion Welds	Gas Pressure Welds 17 Gas Fusion Welds	Gas Pressure Welds 16 Gas Fusion Welds	Thermit Full Fusion Weld	Thermit Full Fusion Weld
14 Type of track	Sap pine ties 7"x9"-8' Slag ballast 8"x11-1/2" double shoulder tie plate double spiked	Sap pine ties 7"x9"-8' Slag ballast 8"x11-1/2" double shoulder tie plate double spiked	Creosoted ties 6"x8"-8'&8'6" 19-1/2" C-C 18" crushed slag ballast 8"x12" double shoulder tie plate	Creosoted ties 6"x8"-8'&8'6" 19-1/2" C-C 18" crushed slag ballast 8"x12" double shoulder tie plate	Creosoted ties 6"x8"-8'&8'6" 19-1/2" C-C 18" crushed slag ballast 8"x12" double shoulder tie plate	Creosoted ties 6"x8"-8'&8'6" 19-1/2" C-C 18" crushed slag ballast 8"x12" double shoulder tie plate	Creosoted oak ties 7"x9"-8'6" 20" C-C 12" crushed stone ballast 7-1/2"x13-1/2" single shoulder tie plate 2 galvanized cut spikes per plate	Creosoted Oak Ties 12" Porphyry granite and volcanic cinder ballast 8"x11-1/2" double shoulder tie plate
15 Cost of weld in place	$12.29	$12.29	$9.54 Gas Fusion Weld $21.19	$14.02 Gas Fusion Weld $29.53	$10.20 Gas Fusion Weld $19.78	$10.30 Gas Fusion Weld $21.62	$16.92	$12.36
16 Work done by railroad, contractor or both	Both	Both	Both	Both	Both	Both	R. R. under contractor's supervision	Contractor
17 Were bars applied after welding in addition to the welding?	No	No	Bars applied to Gas Fusion Welds	Bars applied to Gas Fusion Welds	Bars applied to Gas Fusion Welds	Bars applied to Gas Fusion Welds	No	No
18 Maximum speed allowed	30 M. P. H.	30 M. P. H.	45 M. P. H.	45 M. P. H.	45 M. P. H.	45 M. P. H.	40 M. P. H.	40 M. P. H.
19 Approximate annual tonnage in gross tons-pass., frt. locos. and cars	11,500,000	11,600,000	15,500,000	13,400,000	13,300,000	20,100,000	23,000,000	10,000,000
20 Carries pass. or frt. traffic or both	Both	Both	Freight	Freight	Freight	Freight	Freight	Both
21 Approx. annual max. & min. atmospheric temp.	5°-75°	5°-76°	20°-104°	20°-104°	20°-104°	20°-104°	Portals 0°-98° Center 25°-68°	-15°-86°
22 Type of rail anchor, if used, and number per rail length	Compression clips 2 per tie	Compression clips 2 per tie	Compression clips One per tie per rail for 150 ties at each end of continuous rail. For remainder 6 clips per 39' rail	Compression clips One per tie per rail for 150 ties at each end of continuous rail. For remainder 6 clips per 39' rail	Compression clips One per tie per rail for 150 ties at each end of continuous rail. For remainder 6 clips per 39' rail	Compression clips One per tie per rail for 150 ties at each end of continuous rail. For remainder 6 clips per 39' rail	Improved Fair 16 anchors per 39' rail	Modified Fair 6 per 39' rail 4 against compression, 2 against contraction
23 Is any provision made for expansion at either end of section?	No	No	No	No	No	No	No	No
24 What, if any, creepage has been observed due to traffic or temperature change since rail was laid?	None	None	3/4"	3/4"	3/4"	3/4"	None	None
25 What subsequent work has been necessary due to creepage or expansion?	None	None	None	None	None	None	None	None
26 Maximum wheel load	32,500 lbs.	32,500 lbs.	32,850 lbs.	32,850 lbs.	32,850 lbs.	32,850 lbs.	36,000 lbs.	36,300 lbs.
27 Atmospheric temp. when rail laid & fastened	50°	50°	70°-90°	70°-90°	70°-90°	70°-90°	40°-65°	60°-65°
28 Temperature of rail when laid and fastened	50°	50°	70°-90°	70°-90°	70°-90°	70°-90°	35°-60°	60°
29 In tunnel or open	Tunnel	Tunnel	Open	Open	Open	Open	Tunnel	Tunnel

Summary of Processes

Process	In Tunnels			In the Open		
	Installations	Welded Joints	Failures	Installations	Welded Joints	Failures
"A" Gas Fusion	9	941	63	2	142	----
Removed	4	394	63	----	----	----
Remaining	5	547	----	2	142	----
"B" Gas Fusion	5	343	66	1	162	28
Removed	3	253	52	----	----	----
Remaining	2	90	14	1	162	28
"C" Thermit (Old type)	3	568	146	7	2155	102
Removed	1	168	81	----	----	----
Remaining	2	400	65	7	2155	102
"C1" Thermit (Type K)	3	1228	53	7	2165	21
Removed	1	1052	39	----	----	----
Remaining	2	176	14	7	2165	21
"C2" Thermit (Full fusion)	2	1838	----	----	----	----
Removed	----	----	----	----	----	----
Remaining	2	1838	----	----	----	----
"D" Electric Pressure	1	282	2	7	7277	5
Removed	----	----	----	----	----	----
Remaining	1	282	2	7	7277	5
"E" Gas Pressure Weld (Oxweld)	2	192	----	6	4534	7
Removed	----	----	----	----	----	----
Remaining	2	192	----	6	4534	7

Statement of Additional Failures

Railroad	Location	Process	Date Installed	Failures Previously Reported	Failures This Report	Total Failures
Southern	Alexandria, Va.	"B" Gas Fusion	9–1938	19	9	28
B. & L. E.	River Valley, Pa.	"C" Thermit	10–1935	41	2	43
D. & H.	Schenectady, N. Y.	"C" Thermit	1935	42	2	44
D. & H.	Windsor, N. Y.	"C" Thermit	1935	----	3	3
D. & H.	Comstock, N. Y.	"C" Thermit	1936	----	2	2
B. & O.	Willow Valley, Ind.	"C1" Thermit	6–1939	1	4	5
B. & O.	Tunnelton, Ind.	"C1" Thermit	6–1939	----	9	9
D. & H.	Port Henry, N. Y.	"C1" Thermit	6–1937	3	1	4
D. & H.	Bainbridge, N. Y.	"C1" Thermit	1937	----	7	7
Erie	Otisville, N. Y.	"D" Electric Pressure	10–1939	----	2	2
C. G. W.	Oneida, Ia.	"E" Gas Pressure	5–1939	4	1	5
E. J. & E.	Normantown, Ill.	"E" Gas Pressure	6–1944	----	1	1
E. J. & E.	Frankfort, Ill.	"E" Gas Pressure	9–1944	----	1	1

Report on Assignment 7

Service Tests of Various Types of Joint Bars

Ray McBrian (chairman, subcommittee), J. B. Akers, W. C. Barnes, C. B. Bronson, W. J. Burton, H. A. Cassil, C. M. Chumley, C. J. Code, P. O. Ferris, F. S. Hewes, L. S. Jeffords, G. M. Magee, E. E. Mayo, C. E. Morgan, R. E. Patterson, W. H. Penfield, B. H. Prater, J. C. Ryan, R. T. Scholes, J. G. Wishart.

This is an annual report, presented as information, covering the service performance of different types of joint bars which were installed in each of 9 one-mile locations of new 112-lb. RE rail in the westbound track of the Atchison, Topeka & Santa Fe Railway west of Streator, Ill., in June 1937 and in 12 half-mile locations of new 131-lb. RE rail in the eastbound track of the Pennsylvania Railroad east of Valparaiso, Ind., in August 1937. The south rail only of both tracks had hardened rail ends.

Observations and measurements have been continued on the test track during 1945, the principal measurements including: (a) Joint camber on rail head; (b) rail surface profile; (c) out-to-out distance of bars; (d) bolt tension.

The Rail Committee tests described in this report were carried out by the Engineering Division research staff with funds provided by the Association of American Railroads. V. C. Norman, test assistant, was in charge of the investigation, under the general direction of G. M. Magee, research engineer and E. E. Cress, assistant research engineer.

The Santa Fe test track was installed in 1937 and only minor track maintenance has been performed. The Pennsylvania test track, installed in 1937, was resurfaced in 1939 and 1941 with electric tampers and was raised in 1942 and 1945 by air tamping. From the time the test tracks were installed in 1937 until September 1, 1945, there have been 108 million gross tons of traffic over the Santa Fe track and 145 million gross tons of traffic over the Pennsylvania track.

Joint bars in some locations on the Pennsylvania test track were giving unsatisfactory service and were removed from track. The Evertite bars were removed from location L in April 1941. The AREA 24-in. full bearing bars of location B and the B–19 24-in. controlled bearing head and base bars of location E were removed from track in November 1943. The AREA 36-in. full bearing bars of the north rail in location A, with the exception of the regular test joints, were removed from track in 1944. Only 36-in. bars remain in service in the nine test locations.

Joint Camber

A measure used to judge the surface conditions (combined wear, batter and flow of the rail, and droop of the joint) of rail joints for the various types of bars is the joint camber in a chord length of 34½ in. on the running surface of the rail.

In Fig. 1 are plotted average values for 30 consecutive joints on the control cooled, unhardened north rail and also for 30 consecutive joints on the Brunorized, end-hardened south rail for each of the 9 test locations on the Santa Fe track for the years 1937, 1941, 1944 and 1945. In the figure two points are plotted and connected by a line for each type of joint on each rail giving the camber at ½ in. from the leaving rail end (left point) and ½ in. from the receiving rail end (right point). A point above the zero line in the figure indicates that the rail end is higher than the rail surfaces back 17 in.; if below the zero line, the rail end is lower.

For the unhardened north rail, there has been a marked lowering in the joint camber; for the past several years all the points are below the zero line. The decrease in camber (1937 to 1945) for the rail joints with 36-in. bars in locations Q and R is

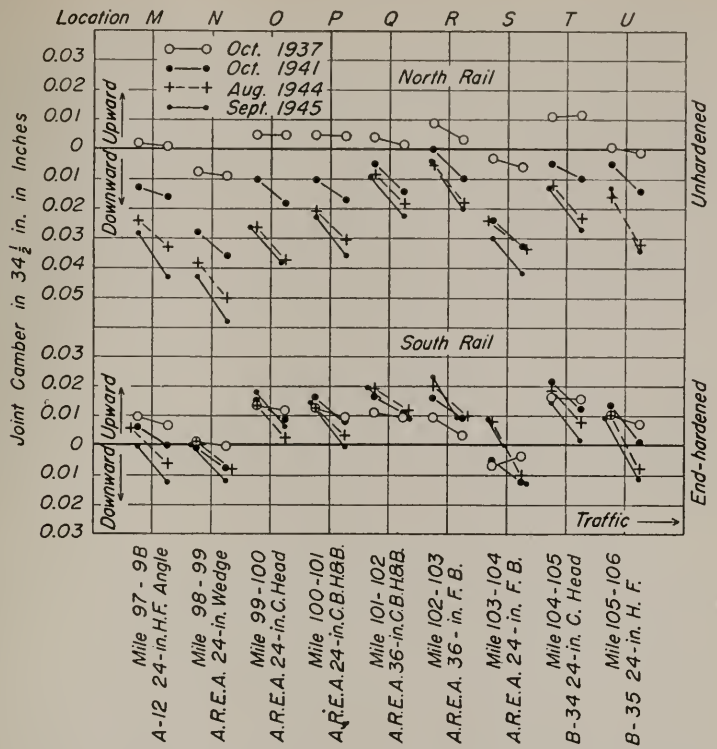


Fig. 1.—Joint Camber in 34½ In. at Leaving and Receiving Rail Ends for 60 Joints in Each Test Stretch on the Santa Fe in 1937, 1939, 1941, 1943, 1944 and 1945.

much less than for any of the other seven locations which are equipped with various types of 24-in. bars. The greatest decrease occurs in location N, AREA 24-in. wedge type joints. In the latter location, the two middle bolts holding the wedges tend to work loose. For the end-hardened south rail, the decrease in joint camber in all 9 locations has been small, probably due to the small amount of rail end batter. In fact, in some locations the 1945 values are slightly higher than the original 1937 values, which doubtless means that the rail surface back 17 in. from the rail end has worn more than the combined wear, batter, flow and droop at ½ in. from the rail end.

Fig. 2 gives corresponding average values for 30 joints on each rail for each of the 12 locations on the Pennsylvania. For the unhardened control cooled north rail, the 9 locations still in service show considerable variation in decrease of camber over the 8-year period. The values show that none of the types of bars is particularly outstanding, and that the headfree bars in locations J and K have the greatest decrease in joint camber. For the field end-hardened south rail, the 9 locations still in service show only small changes in camber over the 8-year period. The frequent reversal of traffic over the test locations on the Santa Fe has doubtless minimized batter differences at the two rail ends of a joint and this probably accounts for the somewhat different camber at the two rail ends of a joint reported for the Santa Fe and the Pennsylvania.

Rail Surface Profiles

Rail surface profiles were taken on the running surface of the rail between points 20 in. back from each rail end. The reference points of the measuring instrument are located on the base of the rail so that head surface wear is included in the measurement and any changes (wear, flow, batter, camber of joint bar, and bending or droop of the joint) occurring on the running surface of the rail can be determined for successive years. Readings are taken by a dial gage on a bar at 22 intervals along the rail surface. The changes in values at the points back 20 in. from the rail ends may be considered a fair indication of the rail head wear between periods of measurement. In Figs. 3 and 4 are plotted average values of elevation of rail surface profile measurements made in 1938, 1941, 1944 and 1945. The 1938 values have been used as a base because the present type of instrument was not developed in 1937 at the time the test locations were installed.

In Fig. 3 are plotted the average rail surface profiles for 15 joints on each rail for each of the test locations on the Santa Fe. Considering the difference in rail height at points back 20 in. from the rail ends, the average rail head wear for the seven-year period between August 1938 and July 1945 amounts to 0.030 in. The outstanding feature of the average profiles for the end-hardened south rail is that the 1938 and 1945 profiles

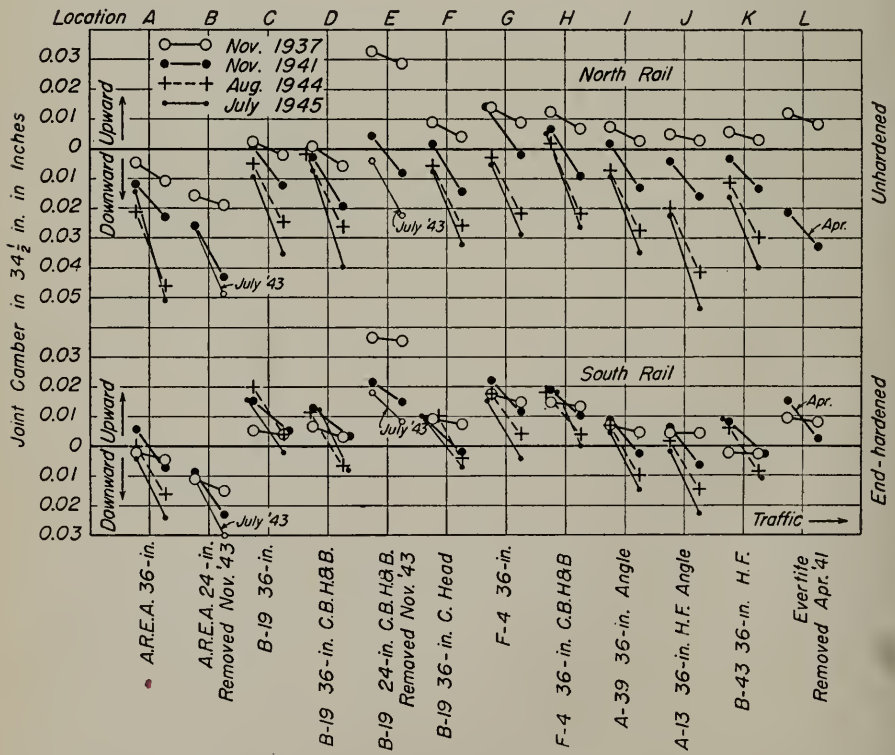


Fig. 2.—Joint Camber in 34½ In. at Leaving and Receiving Rail Ends for 60 Joints in Each Test Stretch on the Pennsylvania in 1937, 1939, 1941, 1943, 1944 and 1945.

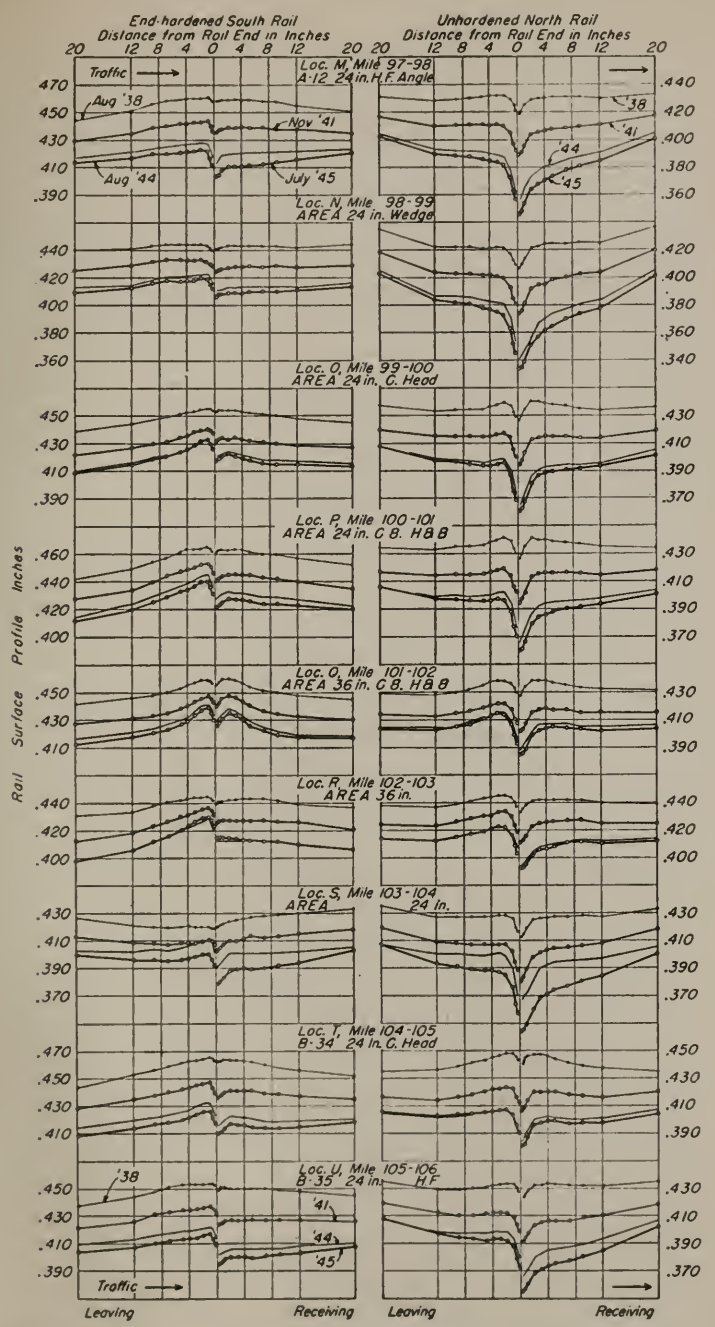


Fig. 3.—Rail Surface Profile for 1938 and 1945—Santa Fe. Average for 30 Joints on Each Location.

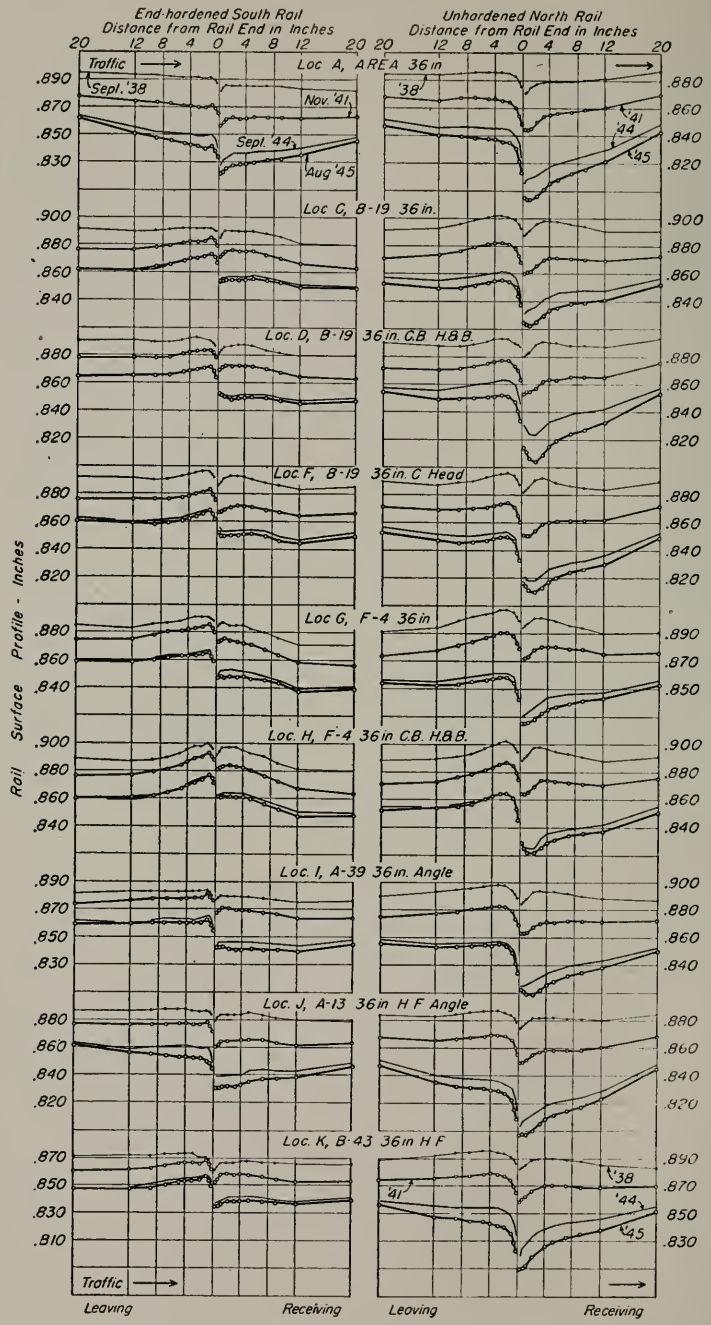


Fig. 4.—Rail Surface Profile for 1938 and 1945—Pennsylvania. Average for 30 Joints on Each Location.

for each of the nine test locations are approximately parallel throughout their 40-in. length. This means that the rail head wear is the only major element that has affected these profiles except for the slight batter at the rail ends. On the unhardened north rail, the batter at the middle few inches is quite marked for all locations and apparently it is causing a varying amount of droop to develop for the seven locations equipped with 24-in. bars. For the north rail, locations Q and R equipped with 36-in. bars have 1945 profiles which show little droop and only a moderate amount of batter. As stated previously the frequent reversal of traffic over the Santa Fe test locations probably accounts for the different profile at the two rail ends of a joint reported for the Santa Fe and the Pennsylvania.

In Fig. 4 are shown the average rail surface profiles for 15 joints on each rail for each of the nine test locations still in service on the Pennsylvania. The average rail head wear at points 20 in. back from the rail ends amounts to 0.034 in. (erroneously reported as 0.034 in. in 1944 instead of 0.031 in.) for the seven-year period between September 1938 and August 1945. On the end-hardened south rail, the average profiles for 1938 and 1945 are reasonably parallel throughout their 40-in. length except for a slight amount of batter at the rail ends. Only locations A and J show a definite droop. On the unhardened north rail, none of the 1945 profiles can be considered parallel to its companion 1938 profile with the possible exception of the leaving rail for location H. A considerable batter has developed on the north rail, accompanied by a droop of the joints in addition to that part due to rail wear and rail batter. This rail end droop is

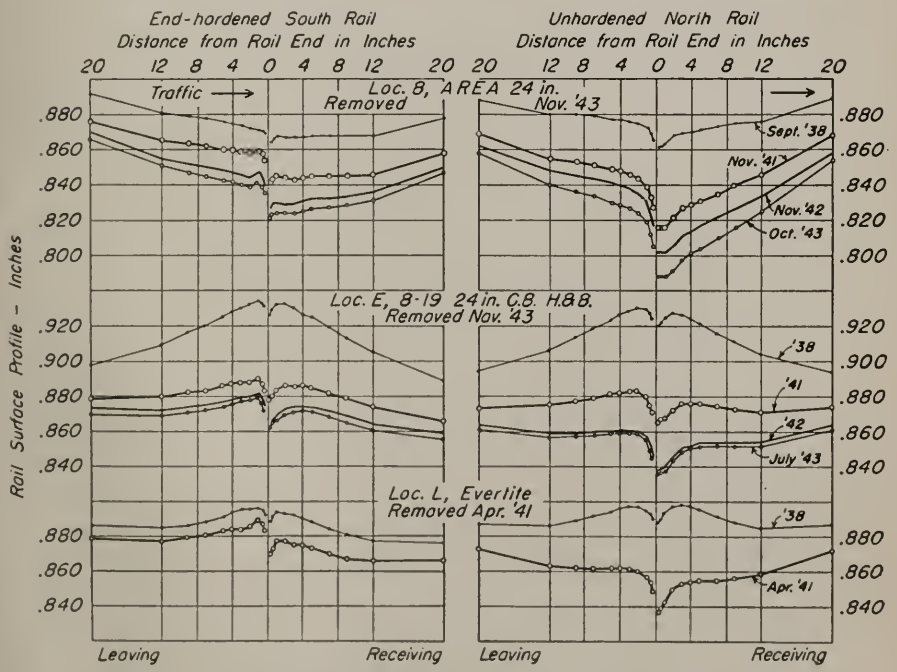


Fig. 4a.—Rail Surface Profile—Pennsylvania. Average for 30 Joints on Each Location. Bars Removed from Service Prior to 1944.

much more noticeable on the receiving rail. The profiles for locations H and I show the least change over the seven-year period while locations A and J present the greatest change.

Fig. 4a shows average rail surface profiles for the three locations which are no longer a part of the Pennsylvania test track. The bars in these locations were removed prior to 1944 due to an unsatisfactory service performance.

In July 1944 the Brinell hardness was obtained for the Brunorized and end-hardened south rails of the Santa Fe test track. Measurements were made on three pairs of rail ends at the middle of the rail head back ½ in. from the leaving and receiving ends. The Brinell hardness ranged from 351 to 380 and averaged 361. Similar measurements were made on three pairs of rail ends on the field end-hardened south rails of the Pennsylvania test track. The Brinell hardness ranged from 364 to 382 and averaged 379.

An inspection for weeping cracks (see Proceedings, Vol. 45, 1944, page 484) was made in September 1945 on the Brunorized and mill end-hardened south rail of the Santa Fe test track. No weeping cracks were found in an inspection of more than 300 of these rail ends. On the Pennsylvania test track an inspection in July 1944 of about 300 rail ends on the south rail disclosed weeping cracks at four rail ends. This rail was end-hardened and water quenched in the field soon after laying by the Graham machine.

TABLE 1.—AVERAGE CHANGE IN OUT-TO-OUT MEASUREMENTS ON JOINT BARS FROM 1937 TO 1945 IN EACH TEST LOCATION ON THE SANTA FE

Values are the combined movements of the two bars. Negative sign means movement towards rail. Each value is the average for 30 joints on each rail. Values are in inches.

Location and Type of Bar	Rail	Top of Bars			Bottom of Bars		
		Leaving end	Mid length	Receiving end	Leaving end	Mid length	Receiving end
		Traffic →			Traffic →		
M. Mile 97–98; A-12	N	—.02	—.06	—.03	—.12	—.14	—.14
24-in. H. F. angle	S	—.03	—.05	—.01	—.10	—.10	—.08
N. Mile 98–99; AREA	N	—.08	—.13	—.11	—.05	—.10	—.09
24-in. Wedge	S	—.09	—.12	—.09	—.06	—.07	—.05
O. Mile 99–100 AREA	N	—.14	—.17	—.18	—.11	—.13	—.14
24-in. C. B. H.	S	—.11	—.13	—.11	—.09	—.11	—.08
P. Mile 100–101; AREA	N	—.14	—.19	—.16	—.10	—.13	—.11
24-in. C. B. H. & B.	S	—.16	—.17	—.12	—.12	—.12	—.08
Q. Mile 101–102; AREA	N	—.10	—.15	—.12	—.07	—.12	—.09
36-in. C. B. H. & B.	S	—.11	—.13	—.13	—.07	—.10	—.10
R. Mile 102–103; AREA	N	—.09	—.15	—.12	—.07	—.13	—.09
36-in. F. B.	S	—.10	—.16	—.10	—.07	—.13	—.07
S. Mile 103–104; AREA	N	—.13	—.18	—.20	—.12	—.15	—.18
24-in. F. B.	S	—.20	—.20	—.18	—.18	—.15	—.14
T. Mile 104-105; B-34	N	—.21	—.20	—.17	—.14	—.14	—.10
24-in. C. B. H.	S	—.22	—.21	—.18	—.19	—.16	—.14
U. Mile 105–106; B-35	N	—.04	—.05	—.03	—.16	—.16	—.15
24-in. H. F.	S	—.08	—.05	—.02	—.23	—.18	—.11

F. B.—full bearing bars; C. B. H. & B.—controlled bearing bars head and base; C. B. H.—controlled bearing bars head only; H. F.—headfree bars.

Out-to-Out Measurements

The out-to-out measurement is the distance between a point on the flange of the outer bar of a rail joint and a corresponding point on the inner bar. Measurements are taken on both the top and bottom flanges of the bars near each end and at the midlength. The main purposes of these measurements are to show the amount and rate of "pull in" of the bars, whether the inward movement is greater at the midlength than at the ends of the bars, and whether any cocking has occurred during a given period. The changes in the out-to-out measurements between 1937 and 1945 are given for the Santa Fe in Table 1. Fig. 5 shows the progressive yearly average change or decrease in out-to-out distances at the midlength of the joint bars for the nine locations on the Santa Fe.

From Table 1 it is seen that the average inward movement at the tops of head contact bars over the eight-year period ranges from 0.08 in. to 0.22 in. and at the bottoms of the same bars ranges from 0.05 in. to 0.19 in. For the two locations with headfree bars, the inward movement at the tops ranges from 0.01 in. to 0.08 in., and at the bottoms ranges from 0.08 in. to 0.23 in.

In Fig. 5 are plotted the average inward movements at the midlength of 30 joints on each rail at each of the Santa Fe test locations. The plottings show that for each of the locations the yearly rate of change in "pull in" is still moderately uniform. For the head contact bars the average yearly "pull in" at the top midlength of bars ranges from

TABLE 2.—AVERAGE CHANGE IN OUT-TO-OUT MEASUREMENTS ON JOINT BARS FROM 1937 TO 1945 IN EACH TEST LOCATION ON THE PENNSYLVANIA

Values are the combined movements of the two bars. Negative sign means movement towards rail. Each value is the average for 30 joints on each rail.
Values are in inches.

Location and Type of Bar	Rail	Top of Bars			Bottom of Bars		
		Leaving end	Mid length	Receiving end	Leaving end	Mid length	Receiving end
		Traffic →			Traffic →		
A. AREA 36-in.	N	—.27	—.26	—.21	—.16	—.15	—.10
F. B.	S	—.20	—.19	—.12	—.14	—.13	—.07
C. B-19 36-in.	N	—.30	—.28	—.26	—.18	—.18	—.17
F. B.	S	—.14	—.20	—.18	—.07	—.14	—.12
D. B-19 36-in.	N	—.21	—.24	—.28	—.17	—.17	—.23
C. B. H. & B.	S	—.09	—.17	—.19	—.04	—.13	—.17
F. B-19 36-in.	N	—.17	—.22	—.22	—.11	—.16	—.18
C. B. H.	S	—.09	—.17	—.15	—.05	—.14	—.13
G. F-4 36-in.	N	—.29	—.30	—.25	—.21	—.21	—.18
F. B.	S	—.18	—.22	—.16	—.12	—.20	—.12
H. F-4 36-in.	N	—.24	—.25	—.28	—.17	—.21	—.22
C. B. H. & B.	S	—.12	—.18	—.16	—.08	—.15	—.13
I. A-39 36-in.	N	—.21	—.23	—.22	—.11	—.11	—.12
F. B. angle	S	—.11	—.18	—.15	—.04	—.08	—.06
J. A-13 36-in.	N	—.08	—.03	—.02	—.19	—.16	—.13
H. F. angle	S	—.01	—.02	—.01	—.11	—.13	—.11
K. B-43 36-in.	N	—.11	—.09	—.03	—.20	—.17	—.11
H. F.	S	—.02	—.08	—.03	—.10	—.15	—.11

F. B.—full bearing bars; C. B. H. & B.—controlled bearing bars head and base; C. B. H.—controlled bearing bars head only; H. F.—headfree bars.

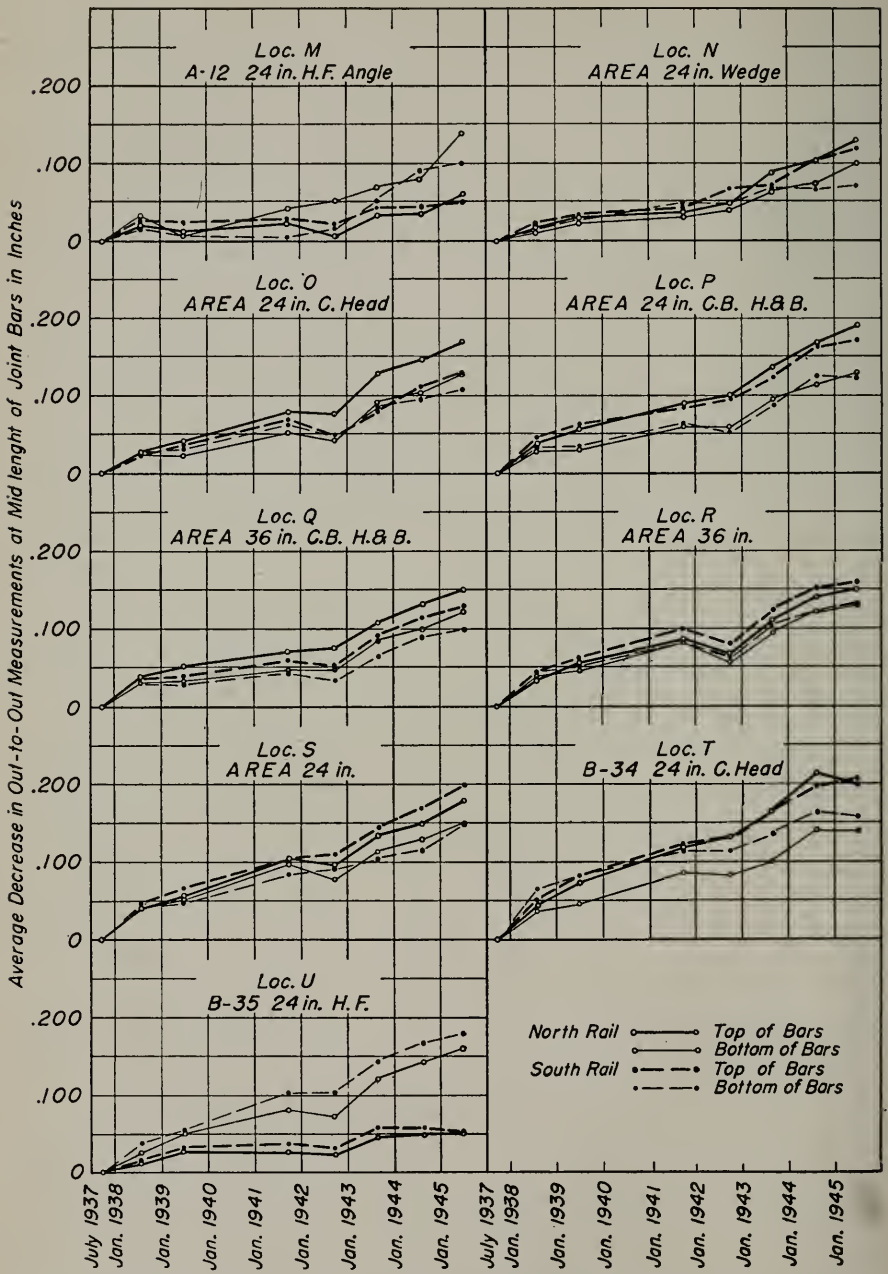


Fig. 5.—Average Annual Change in Out-to-Out Distances of Joint Bars for 60 Joints in Each Test Stretch on the Santa Fe. End-Hardened South Rail, Unhardened North Rail.

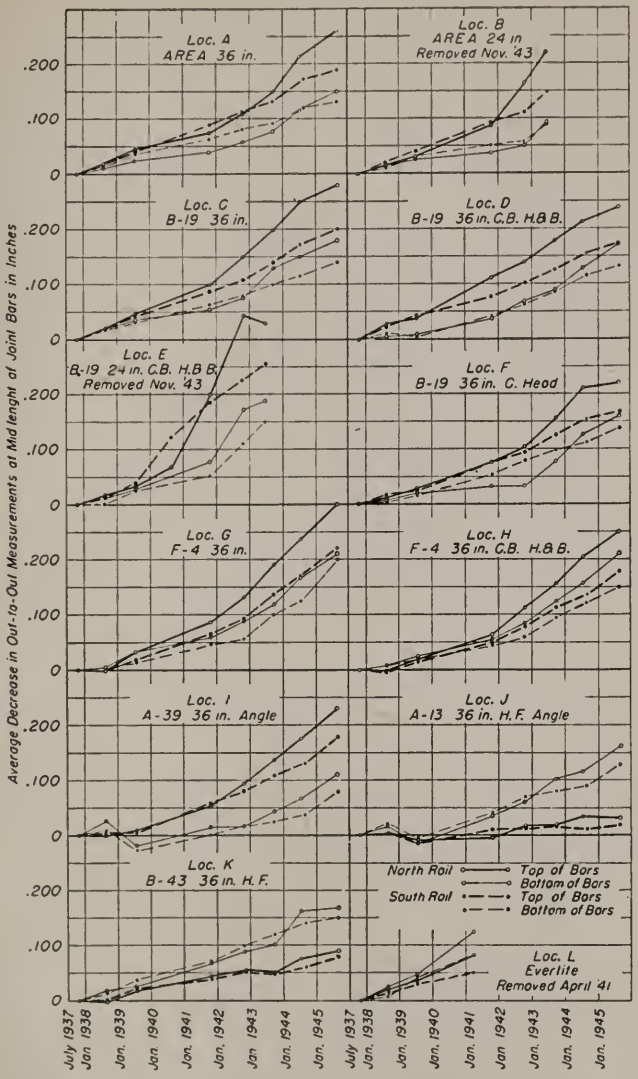


Fig. 6.—Average Annual Change in Out-to-Out Distances of Joint Bars for 60 Joints in Each Test Stretch on the Pennsylvania. End-Hardened South Rail, Unhardened North Rail.

0.015 in. to 0.025 in., with a smaller rate for the bottoms of the bars. For the two locations with headfree bars only a small yearly "pull in" is obtained at the tops of bars, while the bottoms of the bars have an average yearly rate of about 0.02 in.

Similar out-to-out measurements for the Pennsylvania are shown in Table 2 and Fig. 6. From Table 2 it is seen that the total average inward movement at the tops of the head contact bars over the eight-year period ranges from 0.09 in. to 0.30 in., and at

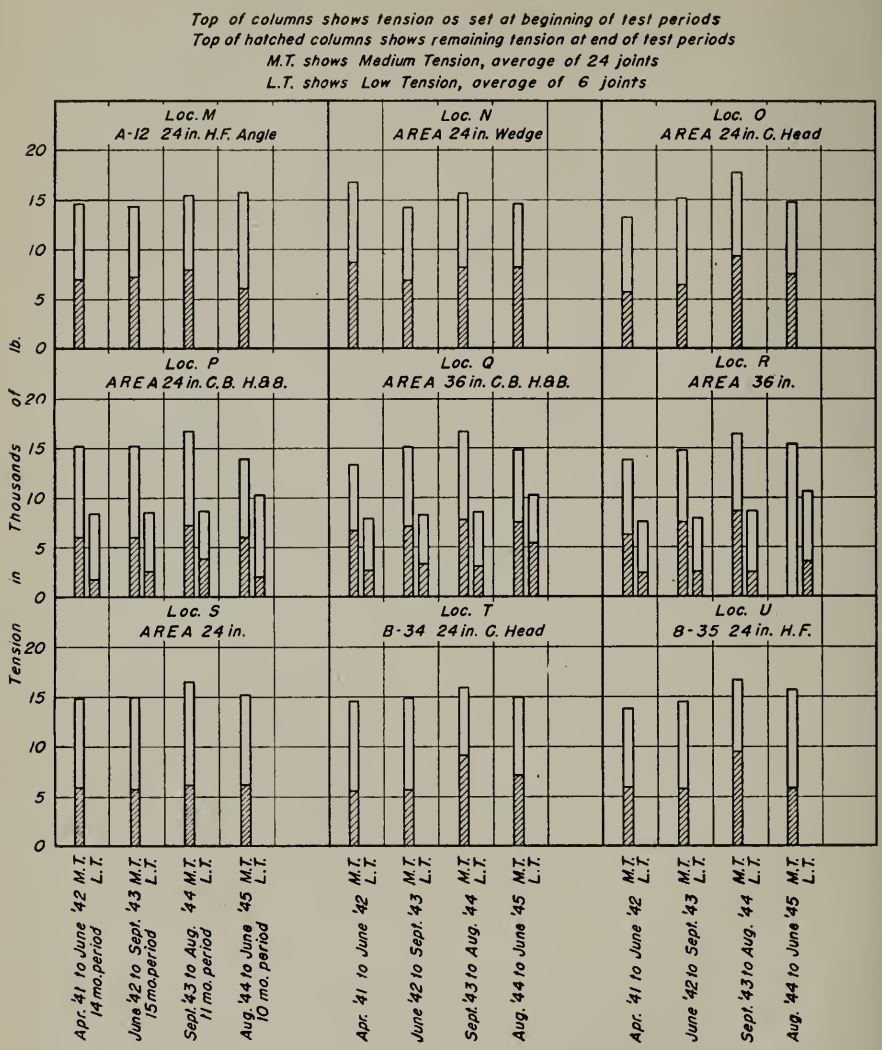


Fig. 7.—Loss in Bolt Tension under Traffic for Stated Periods on the Santa Fe.

the bottoms of the same bars ranges from 0.04 in. to 0.23 in. For the two locations with headfree bars, the inward movement at the tops range from 0.01 in. to 0.11 in. while the values for the bottoms range from 0.10 in. to 0.20 in.

In Fig. 6 it is seen that the rate of change of "pull in" for 1945 is slightly less than for the past two or three years for most of the locations. For the head contact bars the average yearly "pull in" at the top midlength of bars ranges from 0.025 in. to 0.030 in., with a markedly smaller rate for the bottom of the bars.

It will be noted that the values for nearly all the locations in Figs. 5 and 6 are larger on the unhardened north rail where the rail batter is markedly greater.

TABLE 3.—BOLT TENSION ON THE SANTA FE

Values are average of joints in each location. 112-lb. RE Rail. Values are in thousands of pounds.

Location and Type of Bar	Tension as Reset August 1944							Existing Tension June 1945							Loss	
	Lv.	Bolt No.				Rec.		Lv	Bolt No.				Rec.			
	1	2	3	4	5	6	Av.	1	2	3	4	5	6	Av.	lb.	Percent
Medium tension, 24 joints each location		Traffic →							Traffic →							
M. Mile 97–98; A-12 24-in. H. F. angle	17.0	16.0	14.7	15.5	------	------	15.8	7.3	4.8	5.7	6.8	------	------	6.1	9.7	61
N. Mile 98–99; AREA 24-in. wedge	14.5	*	*	14.9	------	------	14.7	8.4	*	*	8.2	------	------	8.3	6.4	44
O. Mile 99-100; AREA 24-in. C.B.H.	17.0	12.5	16.2	13.8	------	------	14.9	9.4	5.1	7.1	8.9	------	------	7.6	7.3	49
P. Mile 100-101; AREA 24-in. C.B.H.&B.	15.2	12.7	14.7	13.2	------	------	14.0	7.3	4.8	6.2	6.3	------	------	6.1	7.9	56
Q. Mile 101-102; AREA 36-in. C.B.H&B.	13.7	17.5	14.3	15.6	14.5	13.9	14.9	8.1	10.7	5.8	6.2	8.1	6.9	7.6	7.3	49
R. Mile 102-103; AREA 36-in. F.B.	15.6	17.8	13.4	14.9	14.6	16.5	15.5	(Bolts retightened in spring 1945)								†50
S. Mile 103-104; AREA 24-in. F.B.	15.8	14.7	14.4	15.7	------	------	15.2	6.8	5.1	5.4	7.4	------	------	6.2	9.0	59
T. Mile 104-105; B-34 24-in. C.B.H.	16.3	13.9	15.7	14.2	------	------	15.0	7.9	4.8	6.9	9.3	------	------	7.2	7.8	52
U. Mile 105-106; B-35 24-in. H. F.	15.0	14.8	16.7	16.5	------	------	15.8	3.8	2.8	6.9	9.9	------	------	5.9	9.9	63
Low tension, 6 joints each location																
P. Mile 100-101; AREA 24-in. C.B.H.&B	9.9	11.2	9.0	11.0	------	------	10.3	2.9	2.8	1.5	1.4	------	------	2.1	8.2	80
Q. Mile 101-102; AREA 36-in. C.B.H.&B.	11.1	8.8	9.3	11.6	11.6	9.6	10.3	4.8	5.5	3.7	6.9	6.4	5.5	5.5	4.8	47
R. Mile 102-103; AREA 36-in. F.B.	11.4	11.5	7.7	10.3	10.1	13.4	10.7	3.9	3.0	3.2	2.2	3.4	6.2	3.6	7.1	66

*Bolt too long for extensometer. †Average for 1942, 1943 and 1944.
F.B.—full bearing bars; C.B.H.&B.—controlled bearing bars head and base; C.B.H.—controlled bearing bars head only; H.F.—headfree bars.

The maximum amount of theoretical "pull in" for most of the joints is somewhat less than 0.40 in. In 1945 an inspection was made to determine whether the ends of the bars were bearing against the upper rail fillets. Sixty joints were inspected in each location on the Santa Fe and Pennsylvania test tracks. Bars with one or both ends bearing against the upper rail fillet were found in every location equipped with the head contact type, except locations N, Q and R on the Santa Fe. This condition was most prevalent in location F on the Pennsylvania where 54 percent of the bars were so affected.

Bolt Tension on the Santa Fe

In June 1945 the bolt tension was measured in 24 joints of each test location and then the bolts were tightened by hand wrenching in all the joints of the test locations on the Santa Fe. In this tightening the bolts were set to a general average tension of about 15,000 lb. for each location. In Table 3 is given the existing tension in June 1945, together with the tension as previously reset in the same joints in August 1944. The average values given are for the bolts in the same 24 joints in each location. The tension reset in the bolts averages 15,100 lb. and the existing tension at the end of the 10-month period averages 6900 lb., which gives an average loss in tension of 8200 lb. In the lower part of Table 3 results are given for three of the locations where the bolts of six joints in each location were set to an average tension of 10,400 lb. The existing tension after the 10-month period averages 3700 lb., a value that must be considered too low for good practice.

In Fig. 7 the open column shows the average tension set at the beginning of a test period and the hatched column shows the average existing tension at the end of the test period. Values for the last four periods of measurements starting in April 1941 until June 1945 are plotted. Half of the joints for each test location are on the unhardened north rail and half on the south rail. It will be seen that for all locations the average existing tension at the end of the test periods is more than 5000 lb. in the medium tension joints.

Bolt Tension on the Pennsylvania

In the upper part of Table 4, 20 joints at each of the nine remaining locations are reported as having been set to a normal average tension of 16,400 lb. in September 1944; the existing tension after the 11-month test period averaged 5700 lb., a loss in tension of 10,700 lb.

In Fig. 8 is plotted the average tension set at the beginning and the remaining tension at the end of five test periods for the individual locations. These last five periods of measurements extend from October 1940 to August 1945. All locations have 20 joints set to a medium tension and 6 joints set to a low tension. Locations J and K, in addition to the above, have six joints set to a high tension. The existing tension in 1945 for medium tension joints is noticeably lower than for any of the other periods.

The data for the Santa Fe and the Pennsylvania show a slightly greater loss in bolt tension and a slightly greater rate of wear or "pull in" for the joints on the unhardened north rail. This fact is attributed to the considerably greater batter on the north rail.

Cracked Joint Bars on the Santa Fe

In 1944, 8 cracked bars in location O and 14 cracked bars in location T were removed from track. In 1945, 60 joints in each location on the Santa Fe test track were inspected for cracks. Ten cracked bars (6 outer and 4 inner) were found in location O

TABLE 4.—BOLT TENSION ON THE PENNSYLVANIA

Values are average of joints in each location. 131-lb. RE Rail. Values are in thousands of pounds.

Location and Type of Bar	Tension as Reset September 1944							Existing Tension August 1945							Loss	
	Lv.	Bolt No.				Rec.		Lv.	Bolt No.				Rec.			
	1	2	3	4	5	6	Av.	1	2	3	4	5	6	Av.	lb.	Percen
Medium Tension, 20 joints each location		Traffic →							Traffic →								
A. AREA 36-in. F.B.	14.7	18.7	14.5	16.4	15.6	16.5	16.1	4.4	3.4	5.1	5.5	5.3	8.6	5.4	10.7	66
C. B-19 36-in. F.B.	15.7	15.9	14.3	14.9	14.9	16.9	15.4	6.4	5.6	3.3	3.9	4.4	5.0	4.8	10.6	69
D. B-19 36-in. C.B.H.&B.	17.9	16.4	14.7	17.2	13.1	16.8	16.0	6.2	6.0	2.6	2.9	5.4	2.4	4.2	11.8	74
F. B-19 36-in. C.B.H.	15.7	16.8	15.6	16.7	16.2	16.0	16.2	8.1	6.6	5.0	6.2	7.4	5.8	6.5	9.7	60
G. F-4 36-in. F.B.	15.8	16.8	14.6	16.3	15.9	16.3	16.0	9.9	5.4	4.7	4.4	5.6	6.2	6.0	10.0	63
H. F-4 36-in. C.B.H.&B.	17.0	20.0	16.0	18.0	15.2	19.3	17.6	7.8	9.2	3.0	2.9	9.5	5.6	6.3	11.3	64
I. A-39 36-in. F.B. angle	15.4	16.8	14.3	16.6	14.5	17.0	15.8	8.8	6.4	5.5	6.1	6.9	6.9	6.8	9.0	57
J. A-13 36-in. H.F. angle	17.0	18.5	16.9	15.3	15.0	15.7	16.4	6.1	4.0	3.8	4.9	3.8	4.8	4.6	11.8	72
K. B-43 36-in. H.F.	16.2	18.4	15.1	19.3	16.9	20.2	17.7	6.9	3.8	5.7	7.1	7.4	9.2	6.7	11.0	62
Low Tension, 6 joints each location																
A. AREA 36-in. F.B.	10.5	10.2	9.5	10.7	10.9	11.6	10.6	9.5	5.4	5.9	0.3	1.2	6.3	4.8	5.8	55
C. B-19 36-in. F.B.	10.8	10.0	11.8	9.7	9.6	10.7	10.4	4.5	2.6	3.1	1.1	2.4	2.9	2.8	7.6	73
D. B-19 36-in. C.B.H.&B.	9.9	10.9	9.8	11.1	9.0	10.8	10.3	4.3	5.2	1.2	2.6	3.2	2.0	3.1	7.2	70
F. B-19 36-in. C.B.H.	9.5	11.2	11.7	10.8	12.1	10.5	11.0	4.3	2.8	1.4	2.6	4.5	4.4	3.3	7.7	70
G. F-4 36-in. F.B.	9.6	10.1	9.8	10.6	12.0	9.9	10.3	4.8	4.8	3.1	1.0	3.7	3.4	3.5	6.8	66
H. F-4 36-in. C.B.H.&B.	12.0	11.9	11.2	10.5	11.1	12.7	11.6	6.2	4.1	1.2	0.5	4.5	2.7	3.2	8.4	72
I. A-39 36-in. F.B. angle	11.8	10.7	10.9	11.7	9.9	11.2	11.0	7.3	5.1	4.6	2.4	3.0	2.9	4.2	6.8	62
J. A-13 36-in. H.F. angle	10.8	8.6	8.8	11.0	10.2	9.7	9.8	2.2	2.0	2.1	1.6	4.1	1.5	2.3	7.5	77
K. B-43 36-in. H.F.	11.5	12.8	11.2	10.7	11.9	13.4	11.9	3.3	2.1	2.5	2.0	2.6	2.1	2.4	9.5	80
High tension, 6 joints each location																
J. A-13 36-in. H.F. angle	21.4	23.5	25.8	23.5	22.4	26.5	23.8	6.8	7.0	12.0	6.4	6.9	9.6	8.1	15.7	66
K. B-43 36-in. H.F.	20.9	22.1	25.7	24.5	25.9	28.7	24.6	12.3	4.4	14.8	9.2	17.0	13.0	11.8	12.8	52

F.B.—full bearing bars; C.B.H.&B.—controlled bearing bars head and base; C.B.H.—controlled bearing bars head olny; H.F.—headfree bars.

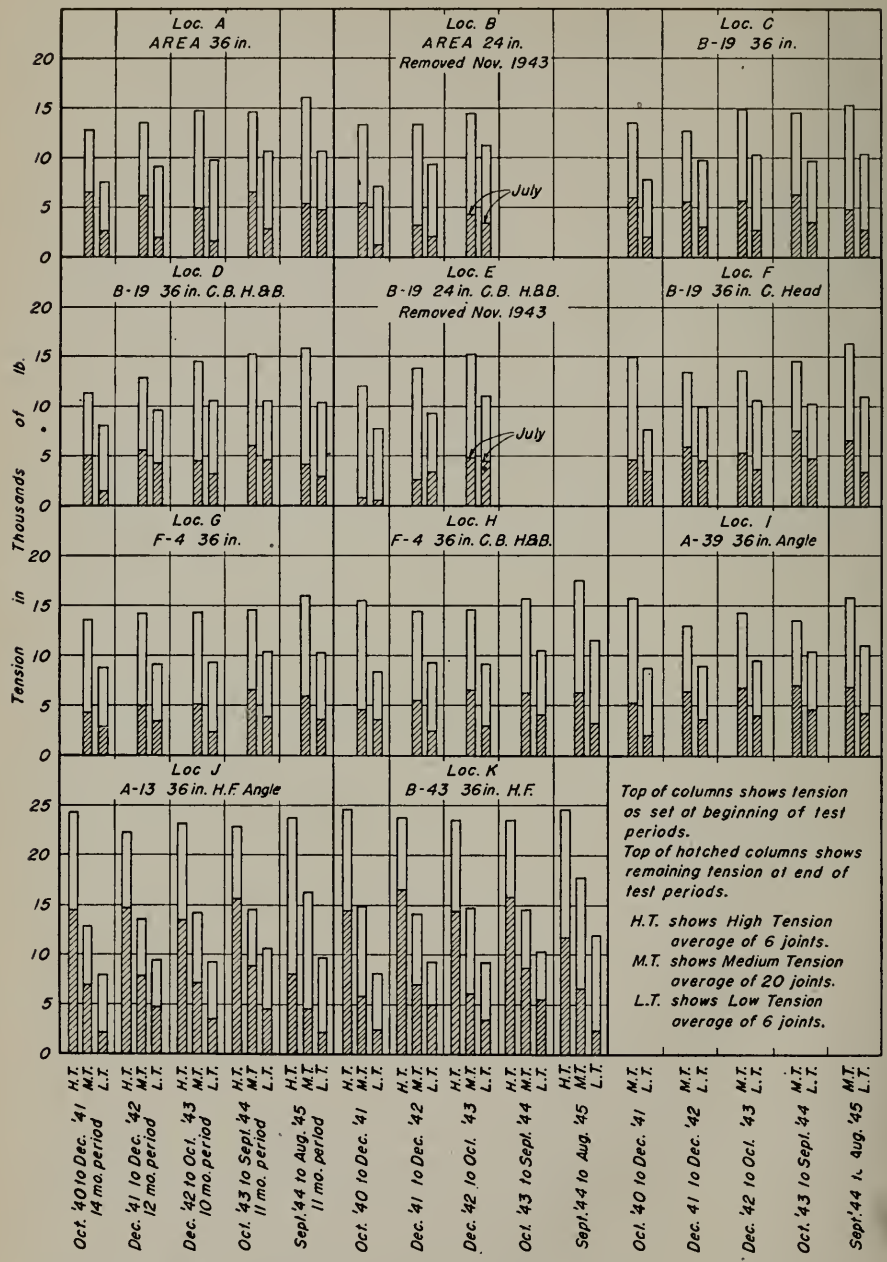


Fig. 8.—Loss in Bolt Tension under Traffic for Stated Periods on the Pennsylvania.

TABLE 5.—RATING OF SERVICE PERFORMANCE OF VARIOUS TYPES OF JOINT BARS AS OF AUGUST 1945. PENNSYLVANIA AND SANTA FE

Best service performance is denoted by 1 and A. Columns 2 and 3 are for unhardened north rail only.

Location and Type of Bar	2 Camber Figs 1 & 2	3 Profile Figs. 3 & 4	4 Out-to-Out Figs. 5 & 6	5 Bolt Tension Figs. 7 & 8	6 Total	7 Rating
Pennsylvania						
A. AREA 36-in. F. B.	3	4	4	2	13	D
B. AREA 24-in. F. B.	Removed	in November, 1943			----	E
C. B-19 36-in. F. B.	1	2	5	2	10	B
D. B-19 36-in. C. B. H. & B.	1	2	4	3	10	B
E. B-19 24-in. C. B. H. & B.	Removed	in November, 1943			----	E
F. B-19 36-in. C. B. H.	2	3	4	1	10	B
G. F-4 36-in. F. B.	2	2	6	2	12	C
H. F-4 36-in. C. B. H. & B.	1	1	5	2	9	B
I. A-39 36-in. F. B. angle	2	1	3	1	7	A
J. A-13 36-in. H. F. angle	4	5	1	3	13	D
K. B-43 36-in. H. F.	3	2	2	2	9	B
L. Evertite 24-in.	Removed	in April 1941			----	F
Santa Fe						
M. A-12 24-in. H. F. angle	4	5	1	3	13	D
N. AREA 24-in. wedge	5	6	2	1*	14	D
O. AREA 24-in. C. H. B.	4	3	3	2	12	C
P. AREA 24-in. C. B. H. & B.	3	3	4	3	13	D
Q. AREA 36-in. C. B. H. & B.	1	1	3	2	7	A
R. AREA 36-in. F. B.	1	1	4	2	8	A
S. AREA 24-in. F. B.	3	3	5	3	14	D
T. B-34 24-in. C. B. H.	3	2	5	2	12	C
U. B-35 24-in. H. F.	2	4	2	4	12	C

*Rating based on a comparison of tension in end bolts for each location.
F. B.—full bearing bars; C. B. H. & B.—controlled bars head and base; C. B. H.—controlled bearing bars head only; H. F.—headfree bars.

with the cracks appearing at the top of the bars and near the end of the receiving rail. No other location disclosed any cracks.

Rating of Service Performance of the Various Types of Joint Bars

A rating of the service performance of the various types of joint bars from test measurements is shown in Table 5 for both test tracks. Four factors are considered: Joint camber or droop and batter as taken from Figs. 1 and 2 for the unhardened rail; area of wear and batter between the 1938 and 1945 profiles for the unhardened rail as taken from Figs. 3 and 4; amount of the fishing surface wear of rail and joint bars reflected by the "pull in" of the bars at midlength as taken from Figs. 5 and 6; and the relative or percentage loss of the applied bolt tension as shown in Tables 3 and 4 and Figs. 7 and 8. The method of rating the bars with respect to each of these individual factors was to rate the best performance as 1, next best as 2, etc., grouping two or more types of bars in one rating if the performance of each was judged to be substantially equal. In column 6 the rating points for the four factors are totalled and in column 7, the various types of bars are grouped into classifications A, B, C, D, E and F in order of their service performance, A being the best. The four factors are weighted equally because the first two are closely related to each other and indicate the smoothness of the running surface over the rail joint and the last two are also closely related to each other and indicate or are affected by the amount of joint bar and rail end fishing surface wear.

Table 6.—Rating of Track Riding Condition—Santa Fe Test Track—August 1945

Location	M	N	O	P	Q	R	S	T	U
No. of impact stresses*	21	59	27	17	10	12	36	13	13
Rating	2	5	3	2	1	1	4	1	1

* Ratings based on number of times impact stress in side frame of freight car truck exceeded 10 percent of the static stress in each test mile.

In August 1945 tests were conducted on the Santa Fe to obtain stress measurements on the side frames of freight car trucks. These tests afforded an opportunity to take continuous records over each of the 9 one-mile locations of the test track and thus obtain data on comparative riding conditions of the various rail joint designs. A study of one record for a train speed of 65 mph. was made in order to compare the riding condition on the unhardened north rail for the several locations. The record shows generally a fairly constant frame stress, indicating smooth riding of the car superstructure. However, at occasional locations the stress record reflects a definite wave form indicating that a bounce of the car body had been set up. Since the spacing of the wave crests corresponds to that of the rail joints, the joints are presumed to have set up the oscillation. The number of times that this impact stress at a critical section of the truck frame exceeds 10 percent of the static stress has been considered a measure of relative riding quality and is given for each test location in Table 6. A rating of 1 indicates the smoothest riding condition. The best results are found for the locations equipped with 36-in. bars.

Conclusions

The service tests have consisted of the installation of 9 different types of joint bars for 112-lb. RE rail on the Santa Fe and 12 different types of joint bars for 131-lb. RE rail on the Pennsylvania, with periodic inspection and measurements of certain characteristics which are judged to be indicative of service performance. The following conclusions seem justified by the results to date.

End-Hardened Rails.—The entire service performance of all the various types of joints on the end-hardened rails for both the Santa Fe and Pennsylvania is outstandingly better than that on the unhardened rails. The rail-end batter is much less and it appears that in general no welding will be required when the bars are replaced on the end-hardened rail, providing a good fishing surface fit is obtained; however some surface grinding may be found desirable.

Rail Head Wear.—The rail head wear at a point 20 in. from the rail end of the 112-lb. RE rails on the Santa Fe averages 0.030 in. for 98 million gross tons of traffic. The similar wear on the 131-lb. RE rails of the Pennsylvania averages 0.034 in. for for 133 million gross tons of traffic. These low rates of rail head wear mean that none of these rails should have to be removed from tangent track for many years due to rail head wear. As would be expected, no difference was observed in the rate of rail wear beyond the rail joint for the various types of bars.

Length of Joint Bars.—The service performance in both test installations definitely indicates that a longer service life may be expected from the 36-in. length bars than from the 24-in. bars, but the relative performance can not be definitely evaluated at this time.

Controlled Bearing Bars.—To date, there is no appreciable difference in the performance of the controlled bearing and full bearing bars of similar design.

Headfree Bars.—The performance of headfree bars with the exception of location J (A–13 36-in. angle) is as good as that of head contact bars of comparable section and length.

Angle Bars.—On the Santa Fe, location M compares favorably with the other locations equipped with 24-in. bars. On the Pennsylvania the A–39 36-in. angle bars in location I are giving the best service performance as of August 1945.

Section Area of Bars.—In the Pennsylvania installation the performance of the relatively light weight section F–4 bar (locations G and H) compares quite favorably with that of the much heavier B–19 and AREA bars.

Special Types of Joints.—The Evertite bars of location L were removed from the Pennsylvania track in April 1941 because of unsatisfactory performance. The two middle bolts of the 24-in. wedge type joints of Santa Fe location M have a tendency to come loose before the periodic yearly bolt tightening. A large proportion of these joints are in good condition; however, some of the individual joints of this stretch are showing a high rate of rail batter on the unhardened rail.

Report on Assignment 8

Investigate Joint Bar Failures and Give Consideration to the Revision of Design and Specifications

Ray McBrian (chairman, subcommittee), J. B. Akers, W. C. Barnes, C. B. Bronson, W. J. Burton, H. A. Cassil, C. M. Chumley, C. J. Code, P. O. Ferris, F. S. Hewes, L. S. Jeffords, G. M. Magee, E. E. Mayo, C. E. Morgan, R. E. Patterson, W. H. Penfield, B. H. Prater, J. C. Ryan, R. T. Scholes, J. G. Wishart.

This is a progress report, presented as information.

The principal work on the assignment during the past year has consisted of the continuation of the rolling-load tests of joint bars being conducted at the University of Illinois under the direction of Professor N. J. Alleman. A progress report giving the results of these tests is submitted as information in Appendix 8-a.

In November 1945, measurements were made on the joint bar test on the Chicago, Burlington & Quincy near Ft. Morgan, Colo. This test was installed in July 1939, in connection with relaying the single-track main line at this location with new 112-lb. RE rail, control cooled but not end hardened. The purpose of the test was to compare the effectiveness of improved metallurgies in resisting the development of progressive cracks at the upper fishing surface of the joint bars near the rail ends. This particular location was selected because trouble had been experienced there with joint bar cracks in the past.

Each test section included 100 pairs of joint bars applied out of face. Five different types of joint bars were included in the test as follows (all were 24-in. 4-hole bars):

Type 1.—Head-contact short-toe joint bar of AREA chemistry and heat treatment and of a design similar to that in which cracks had previously occurred.

Type 2.—Same as type 1 except the top fishing surface of each bar was flame hardened for a distance of six inches at midlength. The Brinell of the hardened area was raised from about 220 to about 300.

Type 3.—Same design and chemistry as type 1, but water quenched from 1550 deg. F. for 40 sec. and then drawn at 800 deg. for one hour.

TABLE 1.—COMPARATIVE CHEMISTRY AND PHYSICAL PROPERTIES

Type	C	Mn.	Treatment	Approximate Average Properties				
				Yield Point psi.	Tensile Strength psi.	Elongation percent	Reduction in Area percent	Surface Brinell
1—HC	0.43	0.59	Common oil quench	79,400	111,400	19.5	46.6	220
2—HC	0.43	0.59	Hardened top center	80,400	114,900	20.5	47.2	300
3—HC	0.43	0.59	Water quenched and drawn	94,490	132,553	16.8	43.5	298
4—HC	0.71	0.74	Oil quenched and drawn	103,733	159,517	16.0	38.5	321

Type 4.—Same design as type 1, but rolled from rail steel billets, oil quenched from 1500 deg. F. for 60 sec. and then drawn at 990 deg. for two hours.

Type 5.—Headfree short-toe joint bar of AREA chemistry and heat treatment.

The chemistry and physical properties of types 1 to 4, inclusive, are shown in Table 1. The headfree bars were a part of the regular relay material for which this information was not obtained. However, it may be presumed to be quite similar to that shown in Table 1 for type 1 bars.

Before the rail was laid and test bars applied, extensive measurements were made on 20 joints of each test section to determine the rail-end fishing height, profiles of the upper rail fishing surfaces, joint bar fishing height, and joint bar camber—both vertical and horizontal. Shortly after the rail was laid, rail surface profiles were taken at each of the same 20 joints and out-to-out readings and bolt tension measurements were made on 10 of the joints. These measurements were to provide basic data from which an accurate evaluation of performance could later be made.

In the measurements made in November 1945, it was desired not to disturb the joint bars and accordingly measurements were made only to determine the change in out-to-out distance of joint bars and the sag or dip at the joints.

The amount of decrease in out-to-out distance is an indication of the amount of joint-bar and rail-fishing surface wear. The results are shown in Table 2 and represent the average of measurements made at both top and bottom ribs at each end and at the center of ten joints in each test section.

Table 2.—Decrease in Out-to-Out Distance. November 1939 to November 1945

	Average Decrease (in.)
Type 1—HC ordinary chemistry	0.092
2—HC hardened top center	0.082
3—HC water quenched, drawn	0.075
4—HC rail steel, oil quenched, drawn	0.053
5—HF ordinary chemistry	0.043

It will be observed from this table that the harder joint bars of type 3 and especially type 4 show a considerably reduced rate of wear. Unfortunately, the rate of wear varies greatly at individual joints. Some joints show almost no wear for the six-year period; others show heavy wear—usually at one end of the joint only—as much as 0.15 to 0.20 in. It should also be recognized that while the performance of the headfree bars is good, it is not a great deal better than for type 1 because the available take-up is only about one-half as great.

In Table 3 is shown the average sag or dip in the rail profile at the joints as measured at a point ½ in. from each rail end with reference to a 36-in. straight edge placed along the rail with its midlength over the joint gap.

It will be noted that the headfree and head contact bars of ordinary chemistry show the best results with respect to surface dip at the joints. However, the amount of dip is so small for all types of bars in the test that definite conclusions are scarcely justified. It should be pointed out that the comparatively large dip for the type 2 bars is due in part to warpage resulting from the flame hardening.

No cracked bars were observed at the time of the November 1945 measurements in any of the types of bars included. Accordingly, little difference in service performance

Table 3.—Sag or Dip at Rail Joints

(In inches at midlength of 36-in. straight edge)

Test Section	November 1939 East Rail End	November 1939 West Rail End	November 1945 East Rail End	November 1945 West Rail End	Increase East Rail End	Increase West Rail End	Average
Type 1	0.000	+0.003	0.023	0.020	0.023	0.023	0.023
Type 2	0.015	0.014	0.042	0.036	0.027	0.022	0.024
Type 3	0.005	0.001	0.035	0.033	0.030	0.032	0.031
Type 4	+0.003	+0.003	0.028	0.027	0.031	0.030	0.030
Type 5	0.000	+0.001	0.020	0.020	0.020	0.021	0.021

Note (+ indicates rail end high instead of low)

between the various metallurgies has made itself evident up to the present time except that the rate of wear is least with the rail steel bars, oil quenched and drawn, and somewhat more with the AREA chemistry bars, water quenched and drawn. Based upon the laboratory rolling load tests, the rail steel bars are expected to be more prone to cracking than the other types tested.

Appendix 8-a

Fourth Progress Report of the Rolling Load Tests of Joint Bars

By N. J. Alleman

Special Research Associate Professor of Engineering Materials, University of Illinois

Introduction and Acknowledgment

This report covers the rolling-load tests on joint bars conducted during the past year in the Talbot Laboratory, University of Illinois, as a part of the work of the Engineering Experiment Station in cooperation with the American Railway Engineering Association Committee on Rail under Assignment 8, Investigate joint bar failures and give consideration to the revision of design and specifications. Ray McBrian, engineer of standards and research, Denver & Rio Grande Western Railroad, is chairman of the subcommittee for this assignment. The work is sponsored and financed by the Association of American Railroads. Acknowledgment is made of the services of Lewis Franklin, mechanician in the Talbot Laboratory shops; Robert Stachurski and Farhang Javid, student test assistants and Russell Jensen, special research associate.

Testing Machines and Test Specimens

The rolling-load testing machine used for the tests was described in the Proceedings, Vol. 40, 1939, page 649. During the past year two more 33-in. stroke machines of the same design were constructed in the physical plant shop at the university. One machine is in operation and the second is being calibrated and adjusted.

The test joint and manner of loading were shown in the Proceedings, Vol. 44, 1943, page 587. Tests described herein and all previous tests reported have been on assembled joints using 112-lb. RE rails and 24-in., 4-hole, joint bars.

The three previous reports on Assignment 8 presented test results on two types of head contact bars, B34 and AREA, and J16 headfree design. Studies were made of the effect of bolt tension, cocked position, bar relief and hot sawing. This report covers 17 tests on joint bars made to determine the effect of increased manganese content on the

fatigue strength. Since bars containing higher manganese were available only of the K2 headfree design with lateral overfill and easement it was necessary to make tests with the same design of bars of regular AREA chemistry to provide a comparison of the effect of the increased amount of manganese. The bars are from four different heats representing three different chemical compositions as shown in Table 1. The physical properties of the four heats are also given. The high manganese bars were obtained from the Southern Railway and all others from the Tennessee Coal, Iron & Railroad Corporation.

TABLE 1.—CHEMICAL ANALYSES AND PHYSICAL PROPERTIES OF K2 BARS

Heat No.	Serial No.	Chemical Composition					Remarks
		C	Mn	P	S	Si	
832934	G71	0.55	0.84	0.021	0.024	0.234	Shell steel
842221	G71	0.55	0.84	0.025	0.030	0.206	Shell steel
856278	F92	0.55	0.98	0.025	0.031	0.229	High manganese
21260	H78	0.44	0.55	0.013	0.029	0.075	AREA chemistry
889163	J28	0.48	0.63	0.036	0.030	0.159	AREA chemistry
AREA specification		(0.35) (0.60)	0.80*	0.04*			

Heat No.	Serial No.	Tensile Strength psi.	Yield Point psi.	Reduc. of Area percent	Elon. 2-in. g. l. percent	Remarks
832934	G71	134, 200	103, 300	36.3	16.0	Shell steel
842221	G71	134, 600	106.400	33.7	17.0	Shell steel
856278	F92	119, 400	82, 600	48.7	19.0	High manganese
21260	H78	117, 500	89, 560	45.3	20.0	AREA chemistry
889163	J28	132, 900	110, 300	43.5	17.5	AREA chemistry
AREA specification		100, 000†	70, 000†	25.0†	12.0†	

*Maximum.
†Minimum requirements.

Results of Rolling Load Tests

In Table 2 the test results are tabulated for the 17 joints tested since the previous report was made. Both heats of "shell steel" bars were stamped G71. The numbers 4 and 1 following the serial number in column 2 identify the last number of the heat. A bar is deemed to have failed when the fatigue break has progressed one-half of the bar height and the cycles for failure are so recorded in column 3. In the fourth column it may be seen that in 12 tests failure was from the lower bar surface, where the tensile bending stress is a maximum. In all cases the fatigue break started in a rail-end gouge or in an area marked by heavy bearing and galling. An examination of both bars after each test usually revealed several short transverse cracks on the upper fishing surface in the vicinity of the rail ends.

In the column headed "Rail End" the type of sawing is indicated. As cold-sawed rail ends were formed by cutting with a hack saw the effect of rail-end distortion was minimized. For the hot-sawed rails a variation in the mill grinding operation to remove fins and burrs was noted, that is, the rails for joints 66, 68 and 70 were given a slight bevel on the fishing surfaces and could be so classified. On the other hand the rails for joint 76 were not beveled but the burrs were removed and very little rail-end distortion could be detected.

TABLE 2.—ROLLING LOAD TESTS ON RAIL JOINTS

Bar Type: 112–K2 HF 24-in. 4-hole Lateral center overfill and easement.
Rails: 112-lb. RE. Bolt: 1-in., heat treated, prestressed.
Maximum postive bending moment: 400,000 in.-lb. Negative moment: 200,000 in-lb.
Wheel load: 44,400 lb. Bolt tension: 15,000 lb.

Joint No.	*Bar Serial No.*	*Cycles for Failure*	*Bar Failure N–North, S–South*	*Hardness BHN**	*Rail End H..Hot-sawed C..Cold-sawed*	*Pinching on Failed Bar—in.*	
						Top	*Base*
60	G71–4	509,000	Base S, 1½ in. back	260	H, Milled, Bevel 1/16x1/8	0.004	0.003
61	G71–1	269,000	Base N, to hole	274	H, Milled, Bevel 1/16x1/8	0.003	0.004
62	G71–4	184,700	Base S, rail end	275	H, No bevel	0.028	0.015
63	G71–1	455,600	Base S, to hole	255	H, No bevel	0.013	0.013
64	G71–4	872,200	Base N, to hole	275	C, bevel 1/8 x 1/8		
65	G71–1	980,700	Base S, to hole	282	C, bevel 1/16 x 1/8		
66	F92	457,500	Base S, rail end	239	H, No bevel	0.018	0.007
67	F92	500,000	Top S, rail end	217	C, No bevel		
68	F92	1,157,400	Base S, rail end	245	H, No bevel	0.022	0.008
69	F92	690,800	Top N, rail end	236	C, No bevel		
70	F92	357,900	Base N, rail end	223	H, No bevel	0.011	0.009
71	H78	880,100	Top N, rail end	217	C, No bevel		
72	G71–4	250,000	Top N, rail end	225	C, No bevel		
73	G71–4	462,300	Base N, to hole	263	C, No bevel	Rails also used on Joint 72	
74	H78	2,000,000	No failure	229–239	C, No bevel	Cracks at top of N bar	
75	H78	750,000	Base N, rail end	226	H, No bevel	0.004	0.000
76	H78	611,600	Base S, rail end	244	H, No bevel	0.019	0.007

*Brinell hardness (3000 kg.) on surface near fracture.

In column 7 the maximum projections on the upper and lower rail fishing surfaces at the rail ends contacting the bar which failed are given for all tests with hot-sawed rails. The projections result in a "pinching" action due to the reduced fishing height over a short distance and the term "pinching" is used in this report to denote any rail-end distortion which interferes with the fit of bars.

All tests were made with a 44,400-lb. wheel load. Tension in the 1-in. diameter prestressed bolts was maintained at 15,000 lb. Bolt tensions were checked and reset if necessary at the following cyclic readings: 100, 600, 30,000, 100,000, 250,000 and thereafter at increments of 250,000 cycles. After the completion of each test, the zero tension for each bolt was recorded and the loss of tension due to bolt creep was calculated. The same bolts were used in successive tests as it was found that after use in a test, loss of tension due to bolt creep was never as high as during the first test.

Loss of bolt tension on the two central bolts was often as high as 50 percent after 100 and again after 600 cycles of testing. Corresponding decreases in tension in the two end bolts was usually of the order of 25 percent.

TABLE 3.—BRINELL HARDNESS OF 112–K2 HEADFREE BARS

Bar No.	Serial No.	Cross Section Position*						Surface†	
		1	2	3	4	5	Av.	Top	Bottom
60N	G71							255	251
60S	G71	277	266	259	241	236	256	273	248
61N	G71	285	278	286	280	268	279	286	282
61S	G71							277	287
62N	G71							263	265
62S	G71	274	277	274	277	262	273	269	277
63N	G71							289	284
63S	G71	277	272	260	256	245	262	282	236
64N	G71	272	283	285	283	269	278	248	277
64S	G71							262	277
65N	G71							292	287
65S	G71	282	277	257	272	266	270	292	282
66N	F92							252	269
66S	F92	290	283	272	282	269	279	228	252
67N	F92							234	245
67S	F92	249	248	248	248	235	246	217	241
68N	F92							216	225
68S	F92	290	280	257	271	268	273	217	225
69N	F92	255	256	256	257	248	254	236	240
69S	F92							240	228
70N	H78	285	286	257	231	244	261	240	217
70S	H78							240	216
71N	H78	229	217	198	235	225	220	236	242
71S	H78							223	242
72N	G71	268	274	272	277	263	270	245	275
72S	G71							284	269
73N	G71	280	272	286	268	265	274	292	279
73S	G71							284	284
74N	H78	235	223	252	252	229	236	236	236
74S	H78							239	229
75N	H78	229	217	187	234	226	218	234	230
75S	H78							230	239
76N	H78							221	241
76S	H78	222	216	196	224	215	214	221	244

*Readings on a cross section cut at a quarter point. (1) inner top flange; (2) outer top flange; (3) web at midheight; (4) inner lower flnage; (5) outer lower flange.

†Surface draw filed to remove scale.

Bar Hardness Readings

Hardness tests are contained in Table 3. For each lot of bars received Brinell tests, with a 3000-kg. load, were made on each bar on the upper and lower surfaces at a quarter point and bars of like hardness were paired for the test. The surface was draw-filed to remove scale and obtain a smooth hardness test surface. In no case was the amount of surface metal removed as much as 0.010 in.

For the 16 tests in which failures were recorded the variation in hardness for the four surface positions ranged from a minimum of 9 points Brinell, joint 68, to a maximum of 53 points, joint 63. After the completion of each test, a section was cut from the broken bar at a quarter point and the hardness was recorded at five positions on the cross section.

For the forthcoming tests on bars for 131-lb. rails, bars were selected at rail yards after taking Brinell readings on a large number of bars, the readings being on the top outer flange near the end. It is expected that variations in hardness from bar to bar will not be as large as those noted in Table 3.

From Table 3 it may also be noted that of the 16 bars broken in six cases the average hardness on the cross section is less than either surface reading, in six cases the cross-sectional average is higher and in four cases the cross-sectional average is between the top and bottom surface readings.

A comparison of the surface hardness near the fracture, Table 2, with that found at the quarter point on the same flange, Table 3, shows a maximum difference of 20 points Brinell for all tests. In only seven tests was the variation greater than ten points and the readings were not consistently higher at either location.

Summary of All Tests to Date

Table 4 is a summary of all tests to date made under identical testing conditions of wheel load, 44,400 lb., and bolt tension, 15,000 lb. For the three rail-end conditions the cycles for failure of each joint are listed followed by the Brinell hardness on the fractured surface and the location of failure, top or bottom flange.

For the shell steel bars the average cyclic life with hot-sawed rail ends was about equal to that for cold-sawed, unbeveled ends. It may be noted that the low cycle value of test 62, hot-sawed, 184,700 cycles, probably was due to excessive rail-end pinching. For test 72, cold-sawed, 250,000 cycles, the surface hardness was the lowest of any shell steel bar tested.

Comparing shell steel bars with cold-sawed rail ends the cyclic life with beveled ends was about twice that for unbeveled ends for bars of like hardness.

The shell steel bar tests indicate that bars in the hardness range of Brinell 250–280 are rather notch sensitive. The increase of notch sensitivity with increased hardness is a conclusion clearly brought out in tests of the fatigue of metals.

An important comparison is that high manganese bars, even with lower Brinell hardness, showed greater cyclic life than the harder shell steel bars. Pinching values, Table 2, for the three hot-sawed tests were of the same order of magnitude.

It should be noted that the K2 bars with present AREA chemistry compare favorably with higher manganese bars in the hardness range of 220–250.

Also listed in Table 4 are the results of tests on AREA and B34 bars of the present AREA chemistry. Variations in hardness, 174 to 262 for the AREA bars and 194 to 244 for the B34 bars, indicate differences in tensile strength from bar to bar of the order of 30,000 lb. per sq. in.

A study of the tests in Table 4 shows no definite superiority for any one design of joint bar.

TABLE 4.—SUMMARY OF TESTS WITH K2-HEADFREE, AREA AND B34 BARS
44,400-lb. Wheel Load and 15,000-lb. Bolt Tension

Condition of Rail End

Hot-Sawed No Bevel	*Cold-Sawed Beveled*	*Cold-Sawed No Bevel*
K2 Bars Headfree Mill Easement Serial G71—Shell Steel 0.84 Percent Mn.		
509,000–260–B	872,200–275–B	250,000–225–T
269,600–274–B	980,700–282–B	462,300–263–B
184,700–275–B		
455,600–255–B	Av. 926,400	Av. 356,100
Av. 354,700		
K2 Bars Bars Headfree Mill Easement Serial F92 0.98 Percent Manganese		
457,500–239–B		500,000–217–T
1,157,400–245–B		690,800–236–T
357,900–223–B		
		Av. 595,400
Av. 657,600		
K2 Bars Headfree Mill Easement AREA Chemistry		
750,000–226–B		880,100–217–T
611,600–244–B		2,000,000–(299–236) No failure
AREA Bars AREA Chemistry		
547,000–213–T		892,800–232–B
221,600–174–B		
690,300–262–B } Milled bar relief, top.		
252,800–202–B }		
B34 Bars AREA Chemistry		
338,500–244–B	(cocked bars)	379,600–205–B
301,000–217–T		387,000–218–B
(194T) } Rail-end bevel		543,000–233–B
274,800(209B) }	Mill bar relief, top	317,500–219–T
		464,400–240–T and B

Tabulated values are: Cycles for failure, hardness at fractured surface and failure, top or base.

Profiles of Hot-Sawed Rails

Fig. 1 pictures the rail fishing surface profiles for the hot-sawed rails of joint 63 showing the maximum rail-end pinching condition encountered. Profiles were taken on the upper and lower fishing surfaces along the center line of bearing of full-bearing bars, and also in the rail head fillet, the nominal center line of bearing of headfree bars.

In Fig. 2 the rail profiles for joint 75 are shown. These rails show the minimum pinching condition found in hot-sawed rail ends.

End beveling appears to be effective in correcting the reduced fishing height for several of the joints tested. However, on rails similar to the long rail of joint 62, Fig. 1, the droop of the top fishing surface is too pronounced to be corrected by beveling. It is possible that the excessive end pinching condition noted on some rails may be attributed to dull hot saws.

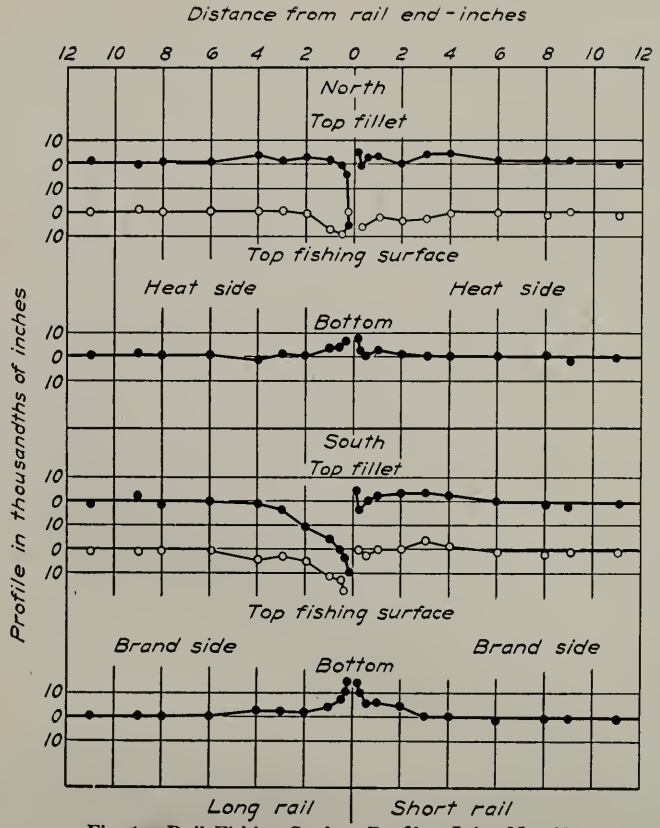


Fig. 1.—Rail Fishing Surface Profiles, Joint No. 62, Hot-Sawed Ends.

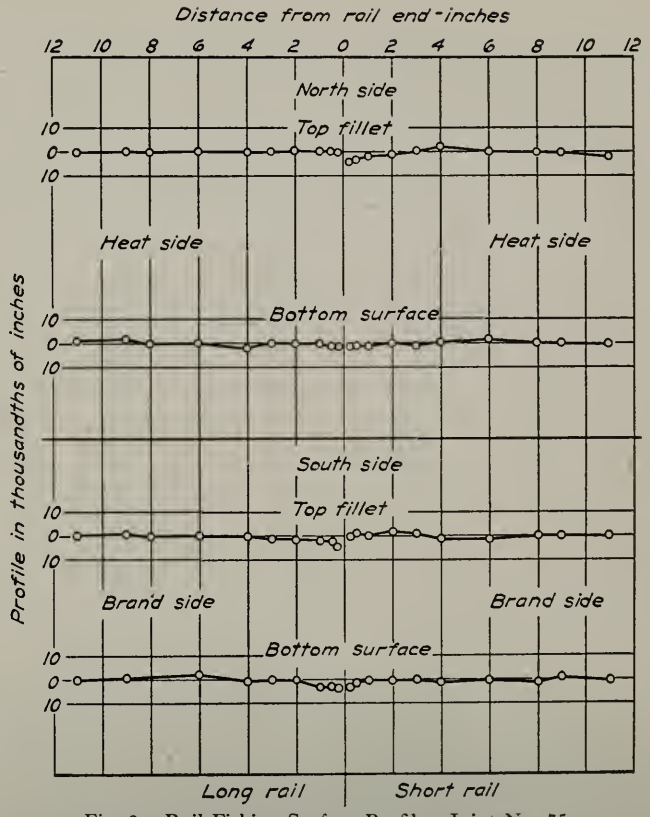


Fig. 2.—Rail Fishing Surface Profiles, Joint No. 75, Hot-Sawed Ends.

Effect of Bar Easement

The drawing for the K2 bar specifies $\frac{0}{64}$ in. lateral overfill on the top surface over the central 6 in. with a tolerance of 0.016 to 0.024 in. The head easement is $\frac{0}{64}$ in., with a tolerance of $\frac{0}{64}$ to $\frac{0}{32}$ in. over a length of approximately 1 in. at midlength.

Fig. 3.—Showing Gouged Top Surface of Bar 64S after 872,200 Cycles. Rail Ends Hack Saw Cut and Beveled. The Lateral Easement Caused the Gouges to be Moved Upward.

Fig. 4.—Top Surface Cracks and Galling on Bar 72S after 250,000 Cycles. Rails Cold-Sawed With No End Bevel. Cracks Outlined With Magnaflux.

The purpose of the easement is to minimize rail-end gouging by eliminating or reducing the effect of rail-end pinching as found on the majority of hot-sawed rails. Fig. 3 shows the gouged top surface of the unbroken bar 64S after 872,200 cycles of testing. The easement has caused the gouges to be moved up on the bar. The mating rail ends were cold-sawed and beveled ⅛ in. by ⅛ in.

Table 5 lists results of bar relief, easement tests on B34 and AREA bars. Using cold-sawed rail ends no appreciable improvement was obtained with a milled relief on B34 bars. The increased life for joint 46 could be attributed to the higher surface hardness. For the AREA bars with hot-sawed rail ends it may be seen that due to "scatter of results" no conclusions would be warranted before making more tests.

TABLE 5.—BAR RELIEF TESTS ON B34 AND AREA BARS

B34 Bars with Cold-Sawed Rail Ends

Jt. No.	*Cycles*	*Pinching*	*BHN Surface*	*Failure*
29	379,600	----------	205	Base S (Cocked bars)
49	387,000	----------	218	Base S to hole
		Milled Bar Relief (Top Only)		
44	317,500	----------	219	Top N to hole
46	464,400	----------	240	Top and Base N

AREA Bars with Hot-Sawed Rail Ends

Jt. No.	*Cycles for Failure*	*Pinching in.*		*BHN Surface*
		Maximum	*Failed Surface*	
53	547,000	0.022 Top S	0.022 Top S	237
55	221,600	0.022 Top N	0.015 Base S	226
		Milled Bar Relief (Top Only)		
54	690,300	0.016 Base S	0.016 Base S	265
56	252,800	0.011 Top N	0.008 Base N	251

Effect of Bar Overfill

The effect of the overfill on the K2 bar is to accentuate the bearing between rail and bar in the region between the central bolts, in the same manner as a shim, giving some lateral spring action to the bar and utilizing better the holding capacity of the end bolts. In all tests some gouging by the rail end is encountered on the top fishing surface, with heavy bearing and galling in the area between the central bolts. In Fig. 4 rail-end cracks (outlined with magnaflux) and the adjacent galling may be noted on the top surface of bar 72S.

Variation of Fishing Height on Brand and Heat Sides

Fishing heights were obtained with a Backes six-point gage on the rails of joints 65 to 76.

This gage contacts the rail at two points 1½ in. apart at the nominal line of bearing on the lower fishing surface, at three points on the web and on the underside of the rail head at the center line of bearing of Full bearing bars. Readings can be taken within ¾ in. of a rail end. The maximum differences of fishing height between the brand side and heat number side on any one rail were 0.024 in. The fishing height on the heat number side is equal to or greater than that on the brand side in all cases observed.

Brinell Survey on Flanges of Bar 63S

Inasmuch as a hardness reading on the lower flange of bar 63S was found to be 46 points Brinell lower than on the upper flange, a longitudinal hardness survey was made on both flanges of this bar with the results shown in Table 6.

Table 6.—Surface Hardness Tests on Flanges of Bar 63S

Distance from Left End—in. (Facing outside bar surface)	*Testing Surface*	*Brinell Hardness 3000 kg. load*
1	Top	283
4	"	283
6	"	282
13	"	282
20	"	288
23	"	302
1	Bottom	268
4	"	217
5	"	Location of micrograph
6	"	235
10	"	255
10¼	"	Fracture
12	"	266
16	"	269
20	"	265
23	"	262

Testing surface smoothed by draw filing, removing approximately 0.01 in. of metal.

The softest location was found to be on the lower flange four inches from the left end. A micrograph, Fig. 5, was made from the transverse face of a section cut at five inches from the left end. It is apparent that the decarburization on the lower bar surface is slight. After observing the mill heat treatment practice it was concluded that during heating the lower bar surface in contact with a water cooled skid was not brought up to the critical temperature or else became cooled below this temperature before quenching.

"Soft" spots on bars in regions other than between the central bolts have not been found to have adverse effects on the fatigue life obtained by rolling-load tests.

Effect of Bar Hardness on Rate of Crack Propagation

An examination of head contact bars during the progress of tests has often revealed top surface cracks after 100,000 cycles, however these cracks do not always lead to bar failure. In several cases cracks were first detected on the top surface of one bar and the joint failed from a fatigue crack on the lower surface of the mating bar.

On headfree bars top surface cracks were seldom found before failure, probably because of their inaccessible location. Upon dissembly of each joint after testing, top surface cracks were found on both bars similar to those previously noted in Fig. 4. Cracks on the lower fishing surface were the exception rather than the rule.

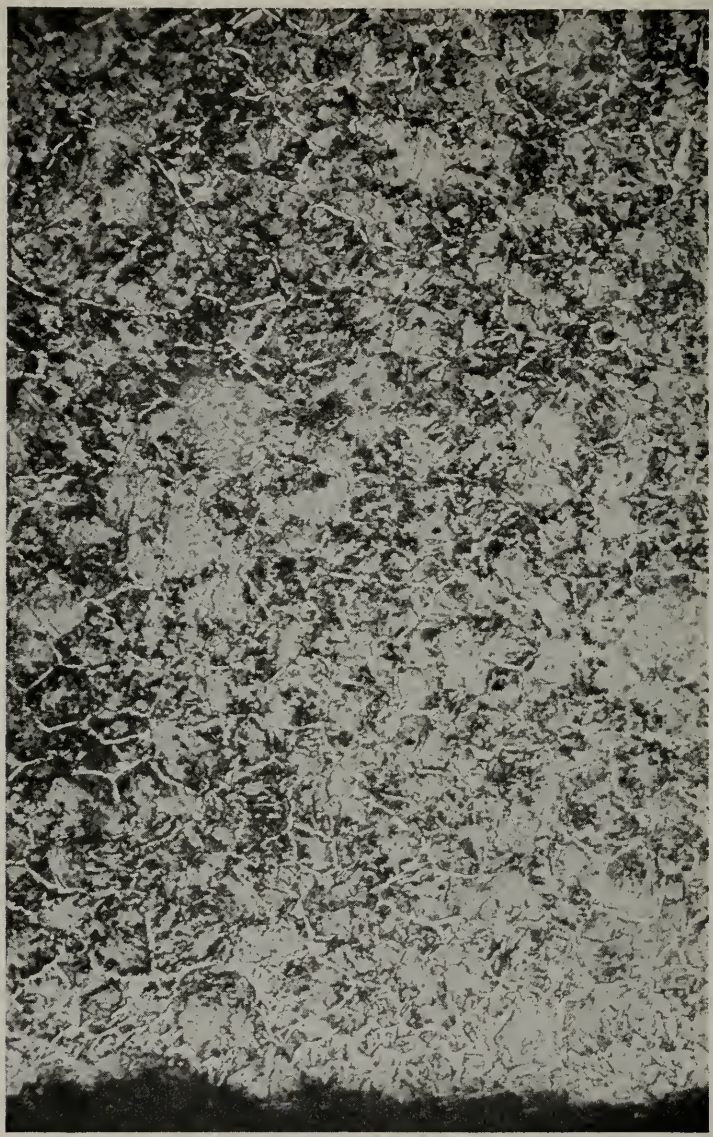


Fig. 5.—Microstructure (X 100 Transverse) at Lower Surface near Fracture of Bar 63S, Showing Slight Decarburization.

The rate of growth of cracks has not been carefully studied but the fatigue fracture in each broken bar has been closely observed. Fig. 6 is typical of the fractures obtained on the comparatively hard shell steel bars. The fatigue crack, outlined by the smooth surface, spread slowly across the lower flange and final fracture as denoted by the rough surface was rapid up to the bolt hole. Photographs of bars of lower hardness, Brinell

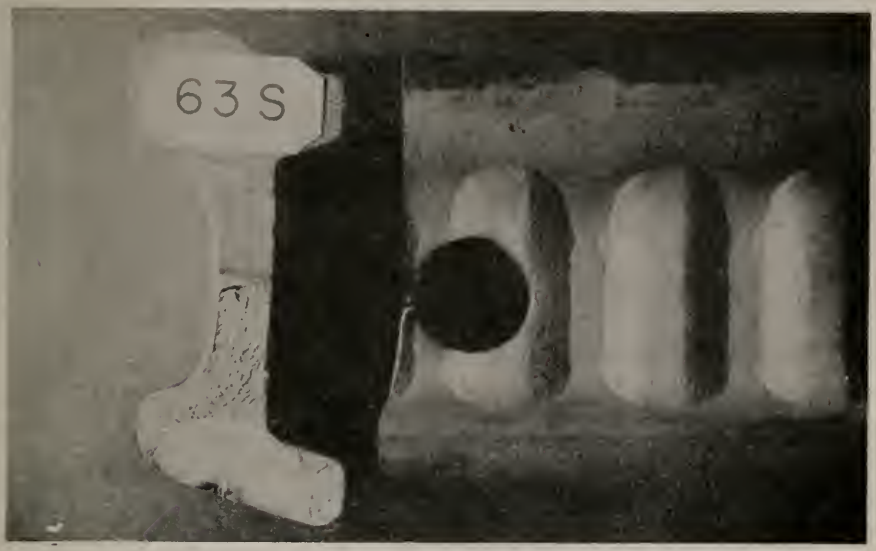


Fig. 6.—Fracture of Bar 63S, Shell Steel, after 455,600 Cycles. Brinell 255 on Lower Surface.

Fig. 7.—Fracture of Bar 67S, 0.98 Percent Manganese, after 500,000 Cycles. Top Surface Brinell 217.

200–210, in previous reports, Proceedings, Vol. 44, 1943, page 593; Vol. 45, 1944, page 442, and Vol. 46, 1945, page 640, show a larger area of smooth surface indicating that the number of cycles from the start of the crack to bar failure was considerably greater than for the K2 bars.

Fig. 7 is representative of the fractures obtained on bars in the lower hardness range. All of the fractured surface is smooth indicating that the rate of growth of the crack was relatively slow.

Inasmuch as the maximum tensile bending stress on the lower surface of the K2 bar at midlength is 42,500 lb. per sq. in. and only 19,600 lb. per sq. in. on the upper surface it seems reasonable to assume that a small lower surface crack will develop faster than one on the upper surface.

Bolts—Calibration, Hardness, Bending by Headfree Bars

The bolts used in this investigation are 1 in. diameter, 6¼ in. long, oval neck and heat treated. After being preloaded three times to 40,000 lb. they are faced on both ends, drilled and calibrated. Bolts calibrated with the nut in two positions, flush with the end of the bolt and turned on an additional ½ in., were found to increase in stiffness, load per unit of elongation, by approximately 8 percent.

Hardness readings on 5 bolts ranged from 223 to 242 Brinell with an average of 231. The test impression was taken on the shank after removing 0.015–0.032 in. of metal to obtain a flat spot. Ten readings on the flat faces of 5 nuts ranged from 153 to 172, with an average of 162 Brinell. Approximately 0.025 in. of metal was removed in preparing the test surface.

Bolts are used on successive tests until they require replacement as cracks develop in the head fillet at the long diameter of the neck. The width of bearing on the underside of the head in this region is rather narrow, about ⅛ in. On the K2 bar tests no bolts have been broken in the threads or shank. However, the outer faces of headfree bars are not parallel and all bolts were observed to be bowed downward at midlength.

Lateral Bar Deflection

Upon assembly of each test joint tightening of the bolts was noted to bend the bars laterally inward at midlength if the rails were cold-sawed and outward with hot-sawed rails. The amount of bending, as much as 0.030 in., varied with individual bars and changed as a test progressed. As the unbroken bar recovered to its original shape upon release of the bolt tension it was apparent that the bending was elastic.

General Observations

1. The mill formed, hot pressed easement on headfree bars reduces but does not eliminate gouging by the rail ends.

2. An examination of bars after testing reveals transverse cracks on the top surfaces in the vicinity of the rail ends.

3. The upper fishing surface of headfree bars soon becomes seated in the rail head fillet and all subsequent lateral bar movement takes place on the lower flanges.

4. After assembly of a joint the outer faces of headfree bars are not parallel and as a result bolts bend in the shank. Bolt head bearing is highest at the end of the oval neck.

Conclusions

1. The data obtained show that hot sawing of rail ends distorts the rail fishing surface, reducing the fishing height in the vicinity of the rail end. The reason for the variation in distortion from rail to rail is not definitely known.

2. Test results indicate that the condition of the rail end, whether hot or cold sawed, or bevelled, has an appreciable influence on the fatigue life of joint bars.

3. The tests indicate that shell steel and high manganese bars are satisfactory if the Brinell values are not too high.

4. A study should be directed towards the metallurgy of a joint bar steel of reduced notch sensitivity.

5. Additional studies should be made to improve the pinched conditions of rail ends.

Report on Assignment 9

Corrugated Rail—Causes and Remedy

Effect Upon Riding Qualities of Tracks and Upon the Costs of Track and Equipment Maintenance

Maro Johnson (chairman, subcommittee), S. E. Armstrong, W. C. Barnes, C. B. Bronson, E. E. Chapman, C. J. Code, J. L. Gressitt, G. M. Magee, Ray McBrian, C. E. Morgan, L. T. Nuckols, R. E. Patterson, W. H. Penfield, A. N. Reece, F. S. Schwinn, F. W. Thompson, R. P. Winton, J. G. Wishart.

This year your committee submits as a progress report—a report by Professor R. E. Cramer, special research associate professor, on an investigation of corrugated rails made by him in 1945 at the University of Illinois. The committee is indebted to Professor Cramer for his work on this subject.

A Preliminary Investigation of Corrugated Rails

By R. E. Cramer

Special Research Associate Professor of Engineering Materials,
University of Illinois

Through the cooperation of Maro Johnson, chairman of the AREA subcommittee on the study of corrugation, and other rail committee members, several specimens of corrugated rails have been sent to the University of Illinois laboratory for study.

These rails have all shown the same characteristics, that is, that the bright spots of the corrugations are hard spots. These areas have been hardened when the slipping wheels heat a thin surface layer above the quenching temperature of the steel, and this layer is quickly cooled by the metal underneath. Numerous other rails have been observed in track which showed continuous hard streaks, but such rails do not receive much attention as they do not become rough. It is only when the hard areas are intermittent and the soft areas between the hard spots cold work lower than the hard areas that the term corrugation is applied to rails. The bright hard streaks can be identified by their mirror like or chromium plated appearance.

Microscopic examination of polished specimens from these rails show the hard layer to be from one to five thousandths of an inch in thickness. Fig. 1 (left) shows a rail received in the laboratory with a continuous hard streak about 1¼ in. in width. Fig. 1

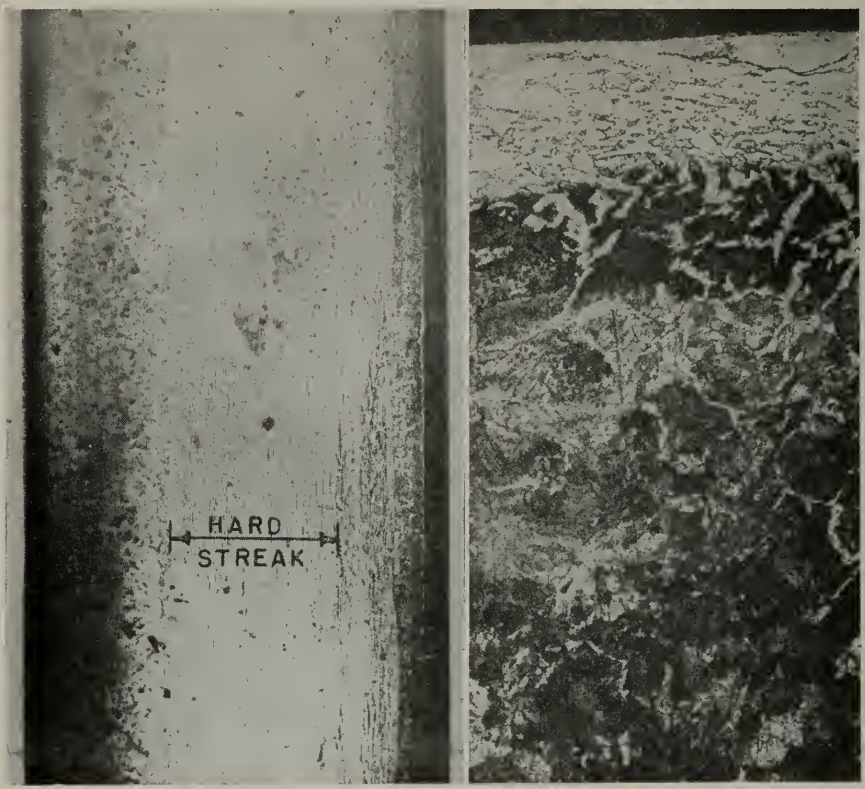


Fig. 1.—Rail With Hard Martensite Streak.

Left.—Tread of rail showing bright streak.

Right.—Photomicrograph at 150X magnification of metal in hard streak, etched in 2 percent nital.

These hard streaks are caused by the drivers of a locomotive spinning while it is moving along at a slow or medium speed. The spinning drivers heat a thin layer of the rail above the quenching temperature, and the metal is quenched to martensite by the underlying metal. Such streaks are usually only a few thousandths of an inch thick, and generally rust and wear off without serious damage to the rail.

(right) is a photomicrograph of a cross section of the hard streak at 150X magnification. The hardness of such thin layers cannot be determined by standard Brinell or Rockwell testing, but the Vicker's Diamond Brinell which uses only a 10-kg. load may be used when the hardened layer is four or five thousandths of an inch thick. Diamond Brinell readings of over 700 have been obtained on two specimens which represents 620 standard Brinell hardness. The structure of the hard areas has been found to be martensite by metallographic examination. This structure can be softened by tempering to a dark straw or blue color.

To determine the effect of flame tempering the hard spots of a corrugated rail, arrangements were made with Mr. Johnson to flame treat such a rail in the freight tracks of the Illinois Central Railroad. The bright spots on half of this rail were heated

Fig. 2 (above).—Tempering Hard Spots on Rail to Remove Corrugation.

The bright, hard spots of a corrugated rail were heated to a blue tempering color with a No. 70 Oxweld torch.

Fig. 3 (right).—Rail One Week After Tempering.

The first three tie lengths were not tempered and still show corrugation. The bright spots on the remainder of the rail have practically disappeared.

to a blue color with a No. 70 Oxweld torch as shown in Fig. 2. One week later the rail was examined and the area which had been flame tempered had lost practically all trace of the bright spots while the untreated portion was still corrugated. Fig. 3 shows three tie lengths of the corrugation and the treated part of the rail at that time.

Flame tempering of either the hard or soft areas of a rail to a blue color which represents about 700 to 800 deg. F. should do no damage to the rail steel as this is about the temperature at which rails are placed in control-cooling containers at the rail mills. It will have practically no effect on the hardness of the soft areas, but will materially soften the quenched martensite areas. Caution should be used to insure that the rails are not heated to a red heat which would be harmful to the rail steel. In service the flame softened hard spots will soon cold work to a smooth running surface with material improvement to the riding qualities of the track. It has recently been called to the writer's attention that corrugation usually occurs simultaneously on both rails of a track as would be expected if caused by wheel slippage. This condition explains why only a few thousandths of an inch difference in elevation of the low and high spots on both rails causes a noticeable effect as the car wheels pass over the corrugated areas.

Some few railroads have grinding cars to remove corrugations. Grinding is undoubtedly the most satisfactory method of reconditioning corrugated rails as it not only removes the high hard spots but would smooth out deep wheel burns as well. However, most railroads do not have special cars for grinding rail surfaces. The method of flame treatment previously described would be available to practically all track men and if properly applied could be the means of preventing the removal of badly corrugated rails as has been reported necessary by a few members of the AREA Rail Committee. Another advantage of the flame treatment would be to remove the martensite areas so the track can be tested for internal defects by the detector cars. When the hard areas are present they act as small permanent magnets and distort the magnetic field around the rail to such an extent as to give many indications of defects.

It can be anticipated that proper tempering of the martensite areas should eliminate this interference but this has not been determined by experiment.

The writer does not mean to contend that all types of corrugation are the results of hard spots caused by wheel slippage. There probably are other service conditions which can cause a rail to become rough, and it is believed this is particularly true of rails in sharp curves which develop relatively long corrugations.

Report on Assignment 10

Development and Characteristics of Fractures Under Engine Burns in Rail

Together with Investigation as to the Effectiveness of Welding Up Engine Burns by Oxyacetylene or Electric Methods

J. B. Akers (chairman, subcommittee), J. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, C. B. Bryant, H. A. Cassil, E. E. Chapman, C. M. Chumley, H. R. Clarke, C. J. Code, G. W. Harris, C. B. Harveson, Maro Johnson, F. R. Layng, H. S. Loeffler, G. M. Magee, E. E. Oviatt, W. H. Penfield, B. H. Prater, J. G. Roney, R. T. Scholes, F. S. Schwinn, F. W. Thompson, R. P. Winton, Louis Yager.

This report is offered as information, with the recommendation that the subject be continued.

Work has been in progress, but has been delayed by breakdowns of the rolling-load machines. The procuring of repair parts has been difficult. An appropriation of $1000 was authorized for 1945, and an appropriation of $11,000 has been approved for 1946. This money will be used for the purchase of one, or if possible two, new rolling-load machines of better design; for the employment of an attendant for the machines; and for other expenses.

Two rolling-load machines are set up in the laboratory of the Southern Railway at Alexandria, Va., and the testing is under the supervision of C. B. Bryant, assistant to vice-president in charge of research and testing for the railroad. One of the machines is loaned by the Sperry Products Corporation, and the other by the Union Carbide Laboratories. Additional testing is being performed by Metal & Thermit Corporation in its laboratory at Woodbridge, N. J.

Twenty-nine specimens have been tested in the rolling-load machines, and may be considered in four groups as follows:

Group 1 represents eight control specimens which are lengths of rail free from known defects, and of the same age in general as specimens in which engine burns are present. These control specimens were to be tested for at least 2,000,000 cycles in the rolling-load machine, with the idea that this number of cycles may represent a practical fatigue limit of rail steel. Five of the specimens did not fail with more than 2,000,000 cycles; three specimens failed due to stress concentrations resulting from corrosion and service. The minimum number of cycles for any of the rails in Group 1 was 1,232,000.

Group 2 includes four engine-burned specimens without fractures beneath the burns, and not welded. One specimen did not fail after 3,136,000 cycles. Failures of the remaining three were outside the engine-burned area, and were due to corrosion and service.

Group 3 includes ten specimens which were engine-burned and subsequently welded to present a smooth surface on the top of the rail. Of this group, five specimens failed due to causes other than the burn or weld; one did not fail after 2,036,900 cycles; one failed after 206,200 cycles due to a progressive fracture from the welded zone, and was probably caused by incomplete elimination of burned metal, or to a thermal crack. This particular rail was the only one tested that had been welded with the electric arc. The remaining specimens ran 1,352,000 or more cycles.

Group 4 includes six specimens of engine-burned rail with fractures beneath them—not welded or built up. Failures in each instance resulted from the growth of the fracture underneath the burn. Three of the specimens failed with less than 94,000 cycles; one with 144,000; two with less than 360,000 cycles.

The testing at the research laboratory of the Metal & Thermit Corporation is intended primarily to determine the growth of fracture under engine burns. The size of the fracture at the beginning of the rolling-load test was determined by the Sperry hand-testing method at the laboratory of the Sperry company. Additional measurements were made by Sperry after each 75,000 cycles. In six rails so tested, there was a pronounced increase in the size of the fracture up to failure, and all of the failures occurred in less than 357,000 cycles, and with three of the failures in less than 94,000 cycles.

In a further effort to determine the effect of engine burns, two new 100-lb. control cooled rails were deliberately burned with a locomotive. Specimens of these fresh burns have been sent to the Northwestern Technologic Institute at Northwestern University for metallurgical examination and a report. Six samples with fresh burns on new rails have been sent to Sperry to determine whether measurable fractures exist, after which those specimens will be turned over to the Metal & Thermit Corporation for the development of fractures underneath the burns, if possible. Other specimens of freshly burned new rails have been welded up, and will be tested in the Southern's laboratory at Alexandria. The work on fresh burns on new rails is just beginning.

No conclusion can yet be drawn, but in general it appears that: (1) A rail containing an engine burn from which a detail fracture has started is likely to fail and should be removed promptly from track; (2) the welding of engine burns apparently results in some improvement of the condition, and rails containing burns that have been welded may be expected to give reasonably good service.

Report on Assignment 11

Investigate Causes of Shelly Spots and Head Checks in Rail Surfaces for the Purpose of Developing Measures for Their Prevention

F. S. Hewes (chairman, subcommittee), S. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, C. B. Bryant, E. E. Chapman, Armstrong Chinn, C. J. Code, P. O. Ferris, J. L. Gressitt, G. F. Hand, C. B. Harveson, Maro Johnson, B. R. Kulp, F. R. Layng, G. M. Magee, E. E. Mayo, Ray McBrian, L. T. Nuckols, W. H. Penfield, B. H. Prater, J. G. Roney, R. T. Scholes, I. H. Schram, Barton Wheelwright, R. P. Winton, Louis Yager.

This report is offered as information.

The report presented by this subcommittee three years ago appears in the Proceedings, Vol. 44, 1943, pages 597–610, that of two years ago in Vol. 45, 1944, pages 446–469 and that of a year ago in Vol. 46, 1945, pages 643–659. References were made therein to the division of the assignment into three groups as follows, which is again followed in this report:

Group 1. Study to be handled directly by the subcommittee:

(a) Mill chemistry record of heats exhibiting these defects.
(b) Tabulation of curvature, elevations, speeds and grades for curves showing these defects.
(c) Effect of rail lubricators.
(d) Transposing rails.
(e) Slow cold rolling.
(f) Field tests of special rails.
(g) Experience of many roads having these defects.

Group 2. Study to be handled by the Engineering Division research staff:

(a) Radius of gage corners of rail.
(b) Tread of wheels, radius between flange and tread of wheels.
(c) Relationship between wear of rail and wheel.
(d) Bearing pressure of wheel on rail.
(e) Cant of rail.
(f) Superelevation of rail on curves.

Group 3. Study to be handled by University of Illinois staff:

(a) Examination of service rail failures caused by these defects.
(b) Rolling-load tests to produce these defects under laboratory conditions.
(c) Resistance of rail steel of various compositions to the development of these defects under laboratory conditions.
(d) Resistance of different heat treatments of rails to the development of these defects under laboratory conditions.

In general, the above outline of the work has been continued during 1945, but the shortage of manpower on the railroads, in the research staff and in the university staff, has hindered the work contemplated by the subcommittee. Funds have been provided by the AAR for the work to be done by Group 2 and by the AAR and the manufacturers for Group 3 throughout 1946 and the best possible use will be made of the available forces and materials.

As the subcommittee continues its investigation and study of this subject, it has been unable as yet to find the solution, but the most promising developments so far appear to be the 3 percent chrome steel and the modified head contours. Field tests of many kinds have been started but have not been in service long enough to furnish conclusions. This shelling is a more serious and wide spread condition than was at first realized, and while the shelly condition may be visible in some cases, in many others, fractures of the rail may occur before there is any evidence of shelling on the surface of the head. In addition to a study of rail steel compositions, heat treatments, rail head contours, wheel and rail contacts and pressures, the subcommittee may turn to a study of mill practices as a possible cause of shelly steel, or it may finally resort to the consideration of larger diameter wheels or lighter loads on the wheels. If the answer lies in some special composition of rail steel or in heat treatment, the investigation must embrace a study of the possibility that the new chemistry or heat treatment may give rise to some other types of defects or that they may lead to excessive difficulties or expense in production. If the answer is found in a special rail head contour, its value for other than shelly territory must be studied.

This assignment has not advanced far enough to warrant any definite conclusions at this time, but the following comments are offered relative to progress made so far, in the order of the groupings given above.

Group 1

Item (a).—A study of data submitted indicates no definite relationship between the chemistry and shelling, except insofar as the hardness of the running surface of the rail is affected.

Item (b).—A study of data submitted reveals no definite trend.

Item (c).—The Delaware & Hudson has a test on two similar curves, one with lubricators and the other without. This test has been in progress about four years, but both curves have developed shelling and flaking spots to approximately the same degree.

Item (d).—Experience on the Milwaukee and the Santa Fe indicates that transposing shelly high rails to the low rail, if done in time, is well worth while.

Item (e).—The Milwaukee reports that moving a good full section rail from the low side of a curve (cold rolled) to the high side after it had been in service on the low side for four years, did not prevent the rail from becoming shelly after two years' service on the high side.

The Norfolk & Western in May and June 1942, relaid in four locations where severe shelling of rail had been encountered, 131-lb. rail that had been taken up after seven years in a single-track light-traffic line. Some shelling developed and these slow-rolled rails have shown very little advantage, if any, over the new high carbon companion rails. Three of the locations were removed in 1944 and 1945.

This railroad in July 1943 relaid approximately thirty 131-lb. RE rails rolled in 1933 which had shown unusual wearing qualities in a heavy-traffic tangent track. These were placed on the high side of a 5-deg. curve in shelling territory. They have developed bad flaking and light shelling. A check of mill chemistry indicates there was nothing unusual about the composition of the steel. These test rails were removed in 1945.

Item (f).—The Norfolk & Western in May, June and July 1941 laid in nine locations with curvature from 3 to 12 deg. where severe shelling of rail had been encountered, four heats of special high carbon rail, with carbon ranging from 0.84 to 0.91 percent, but otherwise conforming to usual specifications. The rail in one location was removed in 24 months and that in another in 40 months, due to a bad shelling condition

and in still another in 25 months due to out of face rail renewals. After four years' service in the remaining six locations, it appears that the high-carbon rail will not eliminate shelling but retards it more than ordinary carbon rail. However, the high-carbon rail has a tendency to head check and this in turn causes gage corner flaking or minute shelling. The sharpest curves did not flake or shell.

In April 1944, this railroad relaid in shelling territory fifteen 130-lb. PS rails that had been removed in an out of face rail renewal in other locations and which were normalized and had $\frac{3}{32}$ in. machined from the head contour. These rails show flaking and considerable shelling.

This same road in August 1944 installed some 3 percent chromium rail, 131-lb. RE section, in shelling territory, on 6-deg. curve. In April 1945, it installed three similar tests on 4, 5 and 7-deg. curves. The rail in the above locations is in excellent condition.

The Duluth, Missabe & Iron Range in April 1943 installed 112-lb. Lorain heat-treated rails on the high and low sides of half of a 4-deg. curve where shelling had been encountered. The other half was relaid at the same time with standard 112-lb. rails. An adjoining 2-deg. curve was similarly handled but on the high rail only. The heat-treated rails show slight checking and flaking; the standard rails, considerable flaking and evidence of initial shelling.

Item (g).—The Duluth, Missabe & Iron Range and the Great Northern have been inspected during the year with respect to their trouble with shelly rails. Both of these roads handle heavy iron ore traffic where this trouble occurs.

Group 2

Part 2 of the assignment is covered by a report prepared by G. M. Magee, research engineer, which follows as Appendix 11-a (page 435), but attention is directed to the following additional remarks:

Item (a).—The Norfolk & Western in May and June 1942 laid at six locations of 2 to 12-deg. curvature, 131-lb. new rail with modified head contour where there had been considerable gage corner shelling. The modified section has a $\frac{7}{16}$-in. gage corner radius, and a 12-in. head radius, these being connected by a 2½-in. radius easement curve. This contrasts with the standard dimensions of $\frac{3}{8}$, 14 and 1 in. respectively. The modified section has retarded flaking slightly better than the standard.

The same road has a test of an equal number of new 131-lb. high-carbon rails and new 130-lb. PS rail installed in one location in December 1942, both high and low rails, where extensive shelling had been experienced in the past. The PS section has a head radius of 12-in. and a $\frac{7}{16}$-in. corner radius, compared with those of the standard 131-lb. RE given directly above, and the head is a little deeper. The specifications were the same for both sections. Both sections have developed a slight amount of flaking but no shelling so far. It is too early to form an accurate opinion at this time.

In fall of 1944 the Norfolk & Western installed about 1000 tons of modified 131-lb. RE section in eight locations with curvatures from 2 to 8 deg. where there had been trouble with shelling. The tests are of too short duration to warrant a report at this time. The modified section has a $\frac{3}{8}$-in. gage corner radius and a 10-in. head radius, these being connected by a 1½-in. radius easement curve.

The Pennsylvania in 1944 installed over 3000 tons of the 152-lb. PS section rail with a modified head contour at certain locations on heavy duty lines, in some portions of which there has been shelling. The modified section has a $\frac{3}{8}$-in. gage corner radius, and an 8-in. head radius, these being connected by a $\frac{7}{8}$-in. radius easement curve. These contrast with standard dimensions of $\frac{1}{4}$, 24 and 1 in., respectively. Performance reports so far indicate slightly less flaking on the modified section than on companion curves with 152-lb. standard rails.

Item (e).—The subcommittee in February 1942 observed shelling of rails laid on a 1:20 cant on the Norfolk & Western and on a 1:40 cant on the Chesapeake & Ohio. The Delaware & Hudson has had a test of rail laid to both cants in service for about four years. No difference in shelling or flaking has been observed.

The Norfolk & Western in March 1944 installed a test of new 131-lb. RE rail on tie plates with no cant, on 4-deg. curve. No flaking or shelling to date, but the gage corner is severely beaded.

Group 3

The third portion of the assignment is covered by a report prepared by Professor R. E. Cramer, which follows as Appendix 11-b (page 443).

Appendix 11-a

Field Investigation by Engineering Division Research Staff

This is the fourth progress report on that portion of the work which has been assigned to the Engineering Division research staff and which is being directed by E. E. Cress, assistant research engineer, under the general supervision of G. M. Magee, research engineer. Earlier reports have included studies of rail and wheel contours and other track conditions that might have a bearing on the development of rail shelling.

During the summer of 1945 extensive stress measurements were made on 131-lb. RE rail in straight and curved track on the Norfolk & Western Railway. Only that portion of the data pertaining to rail shelling is presented here. Randon Ferguson, electrical engineer, and H. C. Roberts, electrical assistant, conducted the field tests.

Later, when the additional data are reduced, they will be reported under Developments Affecting Rail Design.

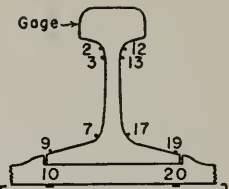
Stress Measurements on Outer 131-Lb. RE Rail of 6 Deg. Curve Under Regular Traffic—Norfolk & Western Railway—1945

Stress measurements were made on the inner and outer rails of a 6-deg. curve and on tangent track on the Norfolk & Western Railway during May, June and July 1945. Stresses were measured with SR-4 wire resistance gages in the upper and lower web fillets, in the upper web and longitudinally on the top of the base on the 131-lb. RE rail. The tests were made on the westbound track of a 6-deg. curve where the traffic is about 60 million tons per year, composed mostly of coal traffic carried in 55, 70 and 90-ton cars. Outer rails formerly in this curve have tended to develop shelling as badly as on any curve of the railway. The present rails laid in February 1945 had not developed head checks, flaking or shelling at the time of the tests (test locations A, B & C, each located one rail length apart). Tests were also made in the eastbound track of the same curve on rail laid in 1936. This rail has not been susceptible to shelling. The same locomotives return on this track but many of the cars are empty coal cars (test locations D, E & F). The tangent track test locations were on the westbound track.

Thus far, only a part of the large amount of test data has been analyzed. This report will be confined entirely to the stresses developed in the outer rails of the 6-deg. curve under the regular train traffic which are of especial interest in the study of rail

TABLE I

RANGE OF MEASURED VERTICAL WEB, FILLET AND LONGITUDINAL BASE STRESSES UNDER LOCOMOTIVE, TENDER AND CAR WHEELS AT SIX LOCATIONS ON THE OUTER RAILS OF A 6-DEG. CURVE ON THE N. & W. RY. - 1945 - TRAIN SPEEDS 5 to 45 M.P.H.



Values are the average of the 3 highest stresses measured at each gage location; Stresses in 1,000 lb.per sq.in. - sign = compression; + = tension; W.B. = Westbound track; E.B. = Eastbound; Rail gages over middle of tie plate.
Note: Locations B & C have new fully rolled crown tie plates, others have original worn rolled crown tie plates.
-- indicates stress so low as to be of no significance.

131-lb. RE Rail	Inner or Gage Side of Rail				Outer Side of Rail				Tie Plate	
	Gage 2 Upper fillet	Gage 3 Upper web	Gage 7 Lower fillet	Gage 9 Base	Gage 12 Upper fillet	Gage 13 Upper web	Gage 17 Lower fillet	Gage 19 Base	Gage 10	Gage 20
Outer Rail -6° Curve				All Locomotive & Tender Wheels						
Sch. 3 - W.B. Loc. A	-36 to + 5	-41 to +13	-22 to + 4	- 8 to +26	-36 to + 3	-40 to +10	-47 to + 2	- 9 to +30	- 1 to + 2	0 to +19
" 4 " " B	-50 to + 5	-35 to +12	-32 to + 4	- 5 to +27	-30 to + 5	-43 to +14	-55 to - 6	- 1 to +31	+ 6 to +24	+12 to +43
" 5 " " C	-37 to + 3	-33 to + 7	-31 to + 4	-13 to +21	-40 to + 7	-35 to + 6	-51 to - 9	- 2 to +34	- 1 to +30	+17 to +39
" 6 E.B. Loc. D	-30 to + 5	-33 to +15	-20 to + 3	- 9 to +24	-42 to + 5	-47 to + 6	-42 to 0	- 2 to +34		
" 7 " " E	-43 to + 9	-33 to +14	-18 to + 2	- 7 to +21	-30 to + 4	-40 to + 9	-35 to 0	- 1 to +45		
" 7 " " F	-34 to + 8	-42 to +13	-34 to 0	- 2 to +22	-50 to + 9	-41 to + 9	-55 to + 2	- 2 to +48		
Outer Rail -6° Curve				All Freight & Passenger Car Wheels						
Sch. 3 - W.B. Loc. A	-19 to --	-20 to --	-11 to --	-- to +14	-14 to + 5	-14 to + 5	-16 to --	-- to +14	0 to 0	-- to + 9
" 4 " " B	-26 to 0	-19 to + 2	-19 to --	- 2 to +21	-18 to --	-16 to + 8	-23 to - 7	-- to +15	+ 7 to +15	-- to +21
" 5 " " C	-23 to --	-15 to --	-21 to --	-- to +19	-18 to --	-15 to --	-29 to --	-- to +18	-- to +20	-- to +23
" 6 - E.B. Loc. D	-18 to --	-17 to --	- 9 to --	-- to +12	-13 to --	-12 to --	-13 to --	-- to +13		
" 7 " " E	-23 to --	-17 to --	- 7 to --	-- to +13	-12 to --	-17 to --	-12 to --	-- to +14		
" 7 " " F	-18 to --	-20 to --	-15 to --	-- to +14	-26 to --	-17 to --	-16 to --	-- to +22		

shelling. In Table I is given the range of measured stresses in the various gages attached to the outer rail. The values in the table are the average of the three highest stresses recorded at each gage location. The range of stress is given for the locomotive and tender wheels and also for the highest stresses recorded under the freight and passenger car wheels. Train speeds were from 5 to 45 mph. Most of the coal traffic was handled by 2–6–6–4 single-expansion articulated locomotives, class A, numbers 1210 to 1234, with 130 or more loaded coal cars per train. Most of these coal trains were running westbound from 25 to 38 mph.

Stresses Under Locomotive and Tender Wheels

From Table I it is seen that the stresses in the upper fillets and upper portion of the web range from —50,000 to +15,000 lb. per sq. in., with approximately the same values on both the westbound and eastbound tracks. The compressive stresses in the lower outer fillets directly over the rolled crown tie plates are the highest recorded at any of the gages.

The nature and magnitude of the stresses recorded at gage lines 3 and 13, located on opposite faces of the upper portion of the web 4⅞ in. above the base, for an individual wheel indicate the position of the centroid of the bearing of that wheel on the rail head. For example, an occasional driving wheel that produced simultaneous stresses of —40,000 and +10,000 lb. per sq. in. in gages 3 and 13, respectively, would indicate that the centroid of bearing pressure was located at or very near the gage corner of the rail (see Fig. 16 AREA Proceedings, Vol. 46, 1945, page 681). These simultaneous stresses at the two faces of the web produce a direct stress in the web of —15,000 lb. per sq. in. which could only be produced by a wheel load of well over 40,000 lb. Very few of the driving wheels running at maximum speeds produce stresses of this magnitude. A second maximum loading condition prevails at a number of drivers where the magnitude and sign of the stresses are reversed from the above example on the two gages, indicating that under these individual wheels the centroid of the wheel pressure comes well towards the outer edge of the rail head. A third condition prevails under many drivers where the stresses at both gages 3 and 13 are about 13,000 lb. per sq. in. compression. This clearly indicates that the centroid of these wheel bearings must come at the middle of the head of the rail, producing only direct compression without bending in the rail section. A fourth condition must exist under a number of wheels where the flange is touching the gage side of the rail and due to a hollow wheel tread another bearing exists outside of the middle of the rail. For this type of wheel bearing the combination of the stresses in gages 3 and 13 would denote the resultant of the two bearing contacts. A motion picture camera, focused at close range on the rail head for a considerable number of wheels on all types of equipment, showed light space between the inner portion of the rail head and the wheel tread, thus indicating that some wheels present bearing conditions of this character. The camera also showed that for some wheels the only bearing contact between wheel and rail was right at the gage corner of the rail at the same location as indicated by the stresses under the first example cited above.

Stresses Under the Wheels of Loaded Coal Cars

In the lower part of Table I the range of stress is given for the wheels of freight and passenger cars passing over the rail. Stresses under some two thousand of the loaded coal cars were recorded. The stresses recorded under the cars were low at all rail gages under all conditions on the outer rails of the 6-deg. curve. In fact it can be stated that their range in stress is about one-half as great as for the wheels of the locomotives and tenders. This is a distinct surprise, because the absence of shelling on the eastbound track

indicates that the freight car traffic is a controlling factor in shelling; however, the stress records are most definite in this respect. As no compressive stress higher than 20,000 lb. per sq. in. was recorded under the car wheels in gage 3, it would seem that the maximum bearing pressures developed at the gage corner of the outer rail where shelling occurs are considerably less than under individual wheels of the locomotives. It is altogether likely that the actual load of an individual wheel of a heavily loaded car varies but a small amount from the average, while it is known that individual locomotive drivers at times produce a very heavy load at the rail. Due to the smaller diameter, the car wheels might possibly produce a more concentrated area of pressure at the gage corner of the rail than do the larger diameter wheels. However, it will be noted that on the rail end stress measurements at gage 3 (see Fig. 3), located directly beneath the gage corner, the maximum dynamic stresses under the wheels of the loaded cars were also only one-half as great as under locomotive wheels. The position of centroid of bearing of the car wheels divide into the same types of positions as described above for the locomotive wheels, but the maximum stresses are much lower. Enough loaded cars passed over the eastbound track to raise the maximum values shown in Table I as high as the values reported for the westbound track, which carries heavy loads almost exclusively. However, the stresses recorded under the wheels of the predominantly empty coal cars in the eastbound outer rail were very low.

The stresses developed in the inner rails of the 6-deg. curve are not reported here. They were found to be considerably greater in magnitude than the stresses in the outer rail.

Conclusions

Stress measurements were made on the rail web and fillets in these tests on the outer rail of the 6-deg. westbound curve which carries loaded coal car traffic and which has developed shelling. Similar measurements were made on the adjacent eastbound 6-deg. curve which carries the same locomotives but mostly empty coal cars and which has not developed shelling. No significant differences were found between the maximum stresses obtained on these two curves to explain the occurrence of shelling on one and not on the other. The measured stresses were higher under the loaded cars than under the unloaded cars, but the magnitude of maximum stresses at all gage locations was only about one-half as great under the loaded coal cars as under individual wheels of the locomotives.

Strains Produced on End of Outer Rail Head of 6 Deg. Curve

Residual Strains at End of New Rail

Measurement of the internal strains developed by traffic at the gage corner of the rail would provide helpful information on the cause of shelling. Since there is no known technique for doing this at the present time, it was considered worth while to measure strains at various locations over the cross section of the rail end, placing wire resistance gages in the joint gap. It is believed that the stresses producing shelling might be somewhat the same at the rail end as elsewhere and shelling has been found at the rail end the same as at other locations along the length of the rail.

During the time of the tests on the 6-deg. curve of the Norfolk & Western Railway, SR–4 ¼-in. length gages were attached to one end of a new 131-lb. RE rail that had not been in track. The rail was not end hardened. The location of the gages on the rail end is shown in Fig. 1. Gages 1 and 2, located on the rail surface at the under side of

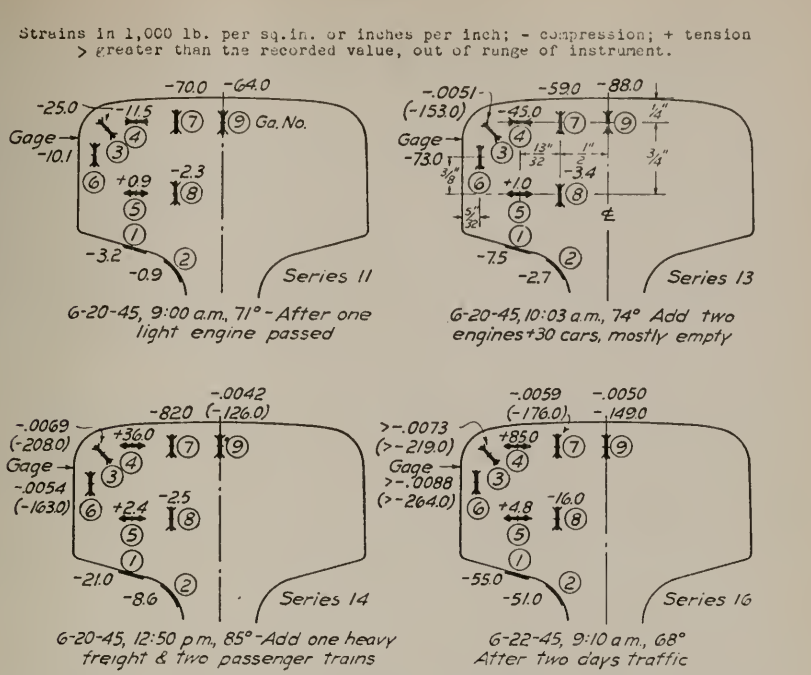


Fig. 1.—Residual Static Strains Developed Under Trains at Gages ¼ In. Long on Leaving End of a New 131-Lb. RE Rail.

Installed June 20, 1945 at 8:15 a.m. on outer rail of a 6-deg. curve on N. & W. Ry. When the residual strain at a gage is greater than 90,000 lb. per sq. in., both the measured strain in inches per inch and the calculated equivalent stress are given. Gages 1 and 2 are back 49 in. from the rail end.

the head and in the upper web fillet, were back 49 in. from the rail end so that they would be away from the rail joint. The new rail was placed in the outer rail of the 6-deg. curve (heavy westbound traffic) with the gages attached to the leaving end of the rail to minimize impact effects. The rail was installed at 8:15 a.m. on June 20, 1945 and a set of zero or reference readings were taken before any wheels had passed over the rail. All later residual strains are with reference to these zero readings.

In the upper left part (Series 11) of Fig. 1 is shown the residual static stresses developed after the passage of one light engine over the rail. These static readings were taken with a portable strain indicator immediately after the passage of this first engine. They do not represent the dynamic stresses occurring as the wheels are passing over the gages but the accumulation of residual stress in the rail to the time the readings were taken. For Series 11 it is seen that the vertical residual stresses recorded in gages 7 and 9 are 70,000 and 64,000 lb. per sq. in. compression, respectively. The residual stress in gage 3 is 25,000 lb. per sq. in. compression. It is probable that the centroid of pressure of all the wheels of this one engine passing at slow speed were concentrated in the middle part of the new outer rail and that the full pressure of no wheel was concentrated directly above gages 3 and 6.

In Fig. 1, Series 13 represents the residual strains after three engines had passed, one of which was pulling 30 coal cars, most or all of the cars being empty. The radial residual strain in gage 3 is —0.0051 in. per in., which would correspond to a stress of

—153,000 lb. per sq. in. if the elastic limit of the material was not exceeded. Gages 3, 4, 6, 7 and 9 record high residual compressive stresses but gage 3 recorded much higher stresses than the others.

In Series 11 and 13 for only one and three engines over the new rail, the residual tangential stress in gage 4 was —11,500 and —45,000 lb. per sq. in., respectively. With the added amounts of traffic of Series 14 and 16, the stress in gage 4 changed sign to tensions of +36,000 and +85,000 lb. per sq. in., respectively. The only reasonable explanation for the compressive stress in gage 4 with just a few wheels over the rail would be that no individual wheel exerted a high vertical pressure directly over this gage as in the case of gages 7 and 9. After considerable traffic, it seems reasonable for the tangential strain in gage 4 to be in tension due to Poissons ratio, assuming that the vertical stress at the same point if it had been measured, would have been in compression and of about the same magnitude as for gages 7 and 9.

In Series 14 and 16 of Fig. 1, representing the effect of up to two days' accumulated traffic, the residual compressive strains in gages 3, 6, 7 and 9 are definitely high. For these gages the strains are given in inches per inch and in parentheses below is given the corresponding stress in thousands of pounds per square inch, although it should be recognized that these strains are so high that they must include some flow and non-elastic yielding of the steel and cannot therefore be used to define the stress by the usual stress-strain relationship. These corresponding stress values are included to give a better picture of the amount of strain to the reader to whom the amount of strain expressed in inches per inch might have little significance. For Series 16, gages 3 and 6 produced strains at the end of two days' traffic that were beyond the range of the recording instrument. It is probable that the residual strain, plastic deformation or flow produced by the high bearing pressures on these two gages was as great as —0.01 in. per in. It was impossible to continue the readings after the two days' traffic because there had been enough deformation of material to loosen the gages recording the high strains from the rail end surface and thus make them inoperative. On the last readings reported there may have been some slippage of the gages, tending to make the actual strains even greater than reported.

Gages 5 and 8, recording the horizontal and vertical residual stresses at positions ¾ in. below the surface of rail, produced low values throughout all series of measurements.

After the two days' accumulation of traffic, gages 1 and 2 at the under side of the head and in the upper web fillet on the gage side of the rail surface back 49 in. from the rail end each indicated slightly over 50,000 lb. per sq. in. compressive residual stress. This is about twice the residual stress developed at similar positions in new rails on tangent track under just a few wheel loads in the Proviso tests (Proceedings, Vol. 46, 1945, p. 679). Residual compression at these locations can be further substantiated by the inspection of rail contours of sharp curves where it has been noted that sometimes the 1 to 4 slope of the under side of the rail head on the gage side has been decreased. Stresses under wheel loads at gage 1 could never exceed ±15,000 lb. per sq. in. and still the residual stress is high at this location.

The middle of gage 3 was located at a point on the rail end corresponding to a point within the rail head where the shelling crack usually starts. This crack occurs along a line perpendicular to the axis of gage 3; therefore it might be expected that the radial stress at this gage location should be tension to cause the opening of the crack.

The residual stresses reported here on the rail end are much higher and sometimes of opposite sign to residual stresses measured by X-ray stress determinations within the head of a rail removed from the outer rail of a curve on the Norfolk & Western,

Residual Strains at End of Used Rail

Gages were attached to the end of the rail that was removed on June 20, 1945 from the outer rail of the 6-deg. curve. This rail had been laid in track in February 1945, and had not been end hardened. The rail was reinstalled in its original position on July 3 with the gages on the leaving end of the rail. A similar test to the one described above was then made. Due to the difficulty experienced in the former test of properly placing seven gages in such a small space, the less important gages, 5, 7 and 8, were omitted in this test.

It must be expected that considerable progressive distortion and flow on the rail end resulting in large residual strains occurred in the four months this rail was in track prior to these tests. The results presented here measure only the additional residual stresses occurring after its reinstallation.

In the upper part of Fig. 2 is given the additional residual static stresses developed after the passage of one light engine and after three engines and a few emepty cars. With this traffic, the only residual stress of any consequence is at gage 9. All other stresses are very low. In the lower part of Fig. 2, representing up to two days' accumulation of traffic additional residual compressive stresses of 88,000 and 98,000 lb. per sq. in. occur in gages 3 and 9, respectively. None of the other gages recorded high residual stresses. It is interesting to note that the low stress in gage 4 is in compression, just as it was initially in the new rail, and that this value later changed to a high tension.

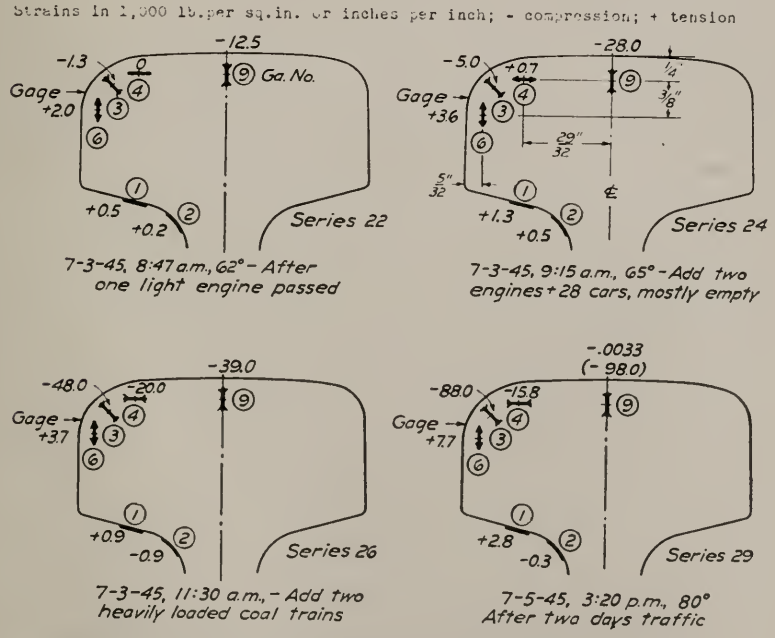


Fig. 2.—Additional Residual Static Strains Developed Under Trains at Gages ¼ In. Long on Leaving End of Original 131-Lb. RE Rail.

Laid in February 1945 in outer rail of 6-deg. curve on N. & W. Ry. Rail removed from track June 20, 1945 for application of gages and reinstalled in same location July 3, 1945 at 8:15 a.m. Gages 1 and 2 are back 49 in. from the rail end.

Dynamic Stresses Under Wheels at End of Used Rail

During the day the original rail was reinstalled in the outer rail of the curve, the leads from the gages were attached to an oscillograph. The dynamic stresses were then recorded under the individual wheels of passing trains. This was a short test, consisting of records under two long heavy coal trains and three passenger trains. The trains were running at speeds of from 30 to 39 mph. The test was made soon after the static readings of Series 26 of Fig. 2 were taken.

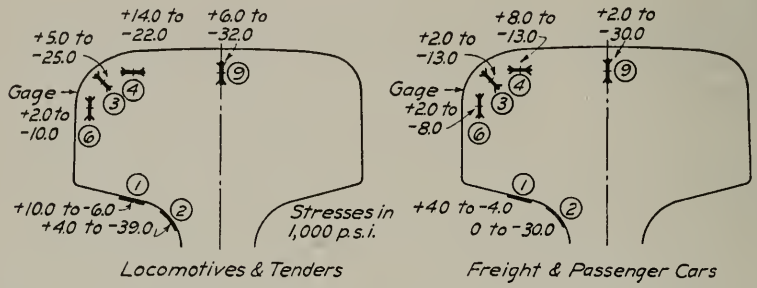


Fig. 3.—Maximum Range of Dynamic Stresses Under Wheels of Passing Trains in Gages ¼ In. Long on Leaving End of Reinstalled Original Rail in Outer Rail of 6-Deg. Curve on N. & W. Ry.
Two freight trains and three passenger trains, July 3, 1945. Gages 1 and 2 are back 49 in. from the rail end.

Fig. 3 shows the maximum range of dynamic stresses recorded under the individual wheels of these passing trains. The left part of the figure gives the range of stress under the locomotive and tender wheels, and the right part of the figure is for the wheels of freight and passenger car wheels. The stresses at the gages on the rail end are all of low or moderate values. The range of stress for each gage is greater under the wheels of the locomotives and tenders than for the car wheels. The range in stress of gage 9 from +6,000 to —32,000 lb. per sq. in. is slightly larger than for any other gage on the rail end. The stresses of gage 6 are quite low, just as were the residual stresses at this gage on this rail. The stress in a leaving rail end gage stays at zero as a wheel approaches to within about 2 or 1 in. of the rail end, then it rises very rapidly to the maximum as the wheel is directly above the rail end. The stress falls to zero almost instantaneously as the wheel leaves the rail end. This rail end had such a small amount of batter that it is probable the wheels made full contact with the rail to the end.

As one tender wheel passed, an offset in the zero stress lines of gages 3 and 9 occurred, denoting additional residual compressive stresses of 5,000 and 9,000 lb. per sq. in., respectively. This occurred even when the compressive stress under the wheel was not over 25,000 lb. per sq. in. While the dynamic records were being made under the five passing trains, the residual static stress in gage 3 increased from —48,000 to —53,000 lb. per sq. in. In gage 9 the increase was from —39,000 to —47,000 lb. per sq. in. None of the other gages had any appreciable change in residual stress during this period.

Conclusions

These tests were of an exploratory nature to determine whether stress measurements could be made satisfactorily within the limited space of the joint gap. The results are presented here as information. These measurements have developed several facts of in-

terest in the investigation of the cause of rail shelling, assuming that the measured stresses at the rail end are at least relative to the internal stresses within the rail head.

1. High residual stresses are developed within the rail head at points where the actual dynamic stresses during wheel passage are well below the yield point of the steel. Presumably residual stresses at these points are "balancing stresses" caused by the yield point being exceeded elsewhere, as for example near the bearing surface.

2. The repetition or reversal of dynamic stresses accompanying wheel passage in the area where shelling develops was not found to be sufficiently high in these measurements to indicate fatigue failure. Computed dynamic shearing stresses from the measured direct stresses were also well below the fatigue strength.

3. Accumulated residual strains were found to be quite high in the area where shelling develops.

4. These measured stresses suggest the possibility that shelling may be the result of exhausted ductility due to excessive plastic flow and high residual strains rather than fatigue of the metal from repeated or reversed stresses.

Appendix 11-b

Fourth Progress Report of the Shelly Rail Studies at the University of Illinois

By R. E. Cramer

Special Research Associate Professor of Engineering Materials
University of Illinois

Organization and Acknowledgment

This work at the university laboratory was previously financed by the Association of American Railroads alone, but beginning January 1, 1945, it was made a part of the Joint Investigation of Failures in Railroad Rails, and financed equally by the AAR and the American Iron and Steel Institute Technical Committee on Rails.

Acknowledgment is made of the advice and help of the members of the joint committee which sponsors this work, and of the aid of F. S. Hewes, chairman of the AREA subcommittee on shelly rail studies. M. C. Moore and L. L. Franklin, mechanicians in the Talbot Laboratory shops; Proal Judson and Jean Louvier, student test assistants and R. S. Jensen, special research associate, have all helped in the laboratory tests.

Study of Physical Properties of Steel in Rails Used for Rolling Load Tests

Physical tests were made of the steel in three rails used in the 1944 rolling-load tests,* and in two newly rolled rails used in the 1945 rolling-load tests. Table 1 lists the results of the physical tests. It will be noted that the two 3-percent chromium rails have very high Charpy values and endurance limits.

Laboratory Rolling Load Tests to Produce Shelling

One rolling machine is used to test specimens machined to a 1-in. wheel path. In previous reports several rails had been rolled to two million cycles without failure. It was desired to determine the relative resistance of these rails to shelling so three of

* Proceedings AREA, Vol. 46, 1945, pp. 649–659, and University of Illinois Engr. Exp. Station Reprint Series No. 32, pp. 28–38.

TABLE 1.—PHYSICAL PROPERTIES OF STEEL IN RAILS USED FOR ROLLING LOAD TESTS

Lab. Rail No.	Kind of Rail	Year Rolled	Yield Strength (0.2% Set) Lb. per Sq. In.	Tensile Strength Lb. per Sq. In.	Elong. in 2-in. Percent	Reduc. of Area Bar	Charpy Value Unnotched Bar Ft.-Lb.	Brinell Hardness Number		Endurance Limit Lb. per Sq. In.
								Before Rolling	After Rolling	
			Rolling Load Tests Reported Last Year							
1081	3% Chromium	1934	128, 000	165, 000	9.3	27	353	376	384	92, 500
814	Sandberg sorbitic	1939	64, 000	122, 700	10.8	28.3	245	237	275	57, 000
810H	Laboratory heat treated int. mn.	1937	117, 500	165, 000	8.1	36.2	317	328	341	73, 500
			Rolling Load Tests in This Report							
823	Inter. manganese	1945	69, 100	127, 000	11.0	32.5	246	257	295	57, 000
1083	3% Chromium	1944	133, 000	177, 000	10.8	41.1	440	387	401	104, 000

*Determined by using fractional width specimens. Reference, S. W. Lyon, Transactions American Society for Metals, Vol. 28, 1940, Page 138.

Fig. 1.—Specimens Rolled in Cradle-Type Rolling Machine.

them were replaced and rolled to five million cycles all without failure. It appears that no additional information can be obtained in a reasonable amount of testing after rolling such specimens to two million cycles. Several other tests were made with specimens machined to a 1-in. wheel path which checked well with tests on the same rails reported last year.

Another rolling-load machine is used which holds a full-section rail specimen in a cradle. The cradle rocks the rail specimen from a vertical position to a position of one to five cant and back to vertical again every 180 strokes of the machine. This produces a type of failure quite similar to shelling as shown in Figs. 1 and 2. Fig. 1 shows the whole specimen after rolling with a ½-in. slice cut out to show the extent of the shelling cracks. Fig. 2 shows the details of the shelling cracks in each specimen.

The bar graph, Fig. 3, shows the number of cycles each specimen was rolled, with the identification and hardness of each rail. Tests reported in previous years have shown

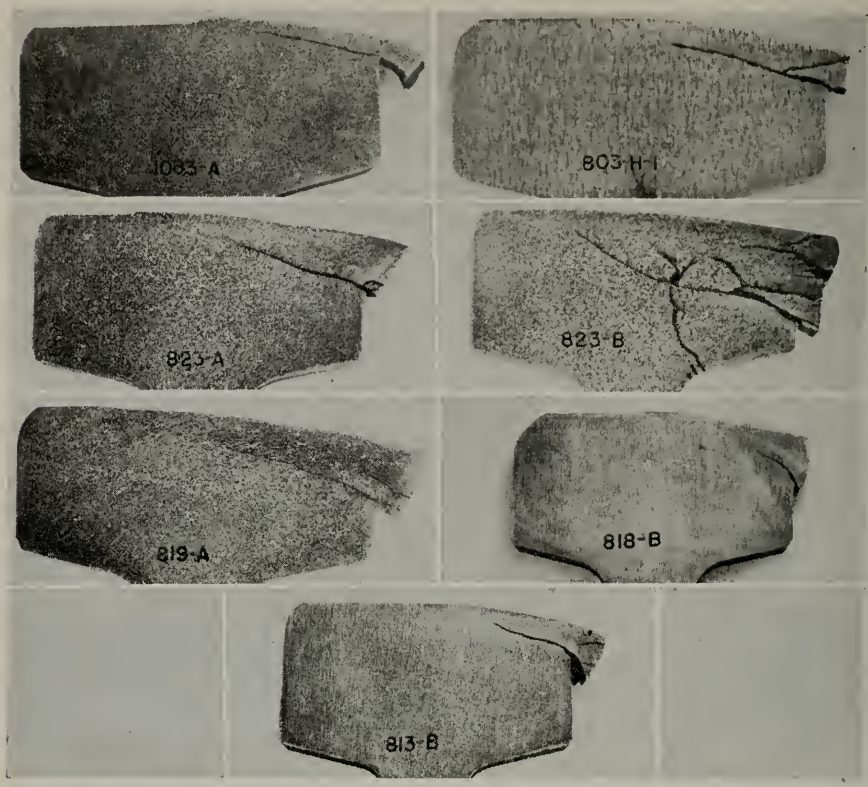


Fig. 2.—Shelling Cracks Developed in Cradle-Type Rolling Machine.

All specimens etched in 50-percent hot hydrochloric acid.
1083A, 3-percent chromium steel, rolled 5,009,000 cycles.
803–H–1, Laboratory heat-treated, carbon steel, rolled 4,564,700 cycles.
823A, Intermediate manganese steel, rolled 1,346,000 cycles.
823B, Intermediate manganese steel, rolled 1,248,000 cycles.
819A, Special radius, 131-lb. carbon steel, rolled 1,112,000 cycles.
818B, Special radius, 152-lb. carbon steel, rolled 1,000,000 cycles.
813B, Mill heat-treated carbon steel, rolled 1,000,000 cycles.

that standard rails would last about 800,000 cycles in the cradle machine. Rails 818 and 819 with radii of approximately $\frac{7}{8}$ in. and $\frac{3}{4}$ in., respectively, on the gage corners withstood 1,000,000 and 1,112,000 cycles. These are the modified head rails used in test track on the Norfolk & Western and the Pennsylvania. Two specimens of intermediate manganese rail, numbers 823A and 823B, rolled 1,248,000 and 1,346,000 cycles, respectively. One rail specimen of carbon steel, number 803–H–1, heat-treated in the laboratory to 368 Brinell hardness, withstood 4,564,700 cycles, while a mill heat-treated specimen, number 813B of 340 Brinell hardness, rolled only 1,000,000 cycles. This mill heat-treated rail was quenched from the rolling heat. It is considered more desirable to allow rail steel to cool below the critical temperature and then reheat to quenching temperature. The three-percent chromium rail specimen, number 1083A, withstood 5,009,000 cycles. It is believed these tests indicate the superiority of the three-percent chromium steel rail, and give some hope that a heat-treated rail may be developed to resist shelling in service. Arrangements have been made to obtain other specimens of alloy steel for laboratory rolling load tests.

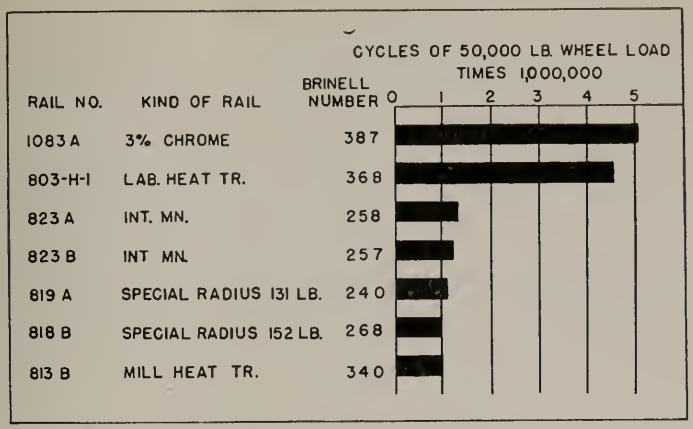


Fig. 3.—Summary of Rolling Load Tests Made in Cradle-Type Machine.

Table 2.—Summary of Observations on High Rail of Four Curves

Data on Curves	*Million Gross Tons Traffic*	*Observations*		
		June—1943	*June—1944*	*June—1945*
Dillon, Va., No. 192.6R East of tunnel Curvature 5° 10′ Superelev. 3¼ Avg. speed 40 mph. Laid new Jan. 1943	1944 45.4 1945 82.0	Avg. Brinell 10 rails 272 Very slight flow at gage corner	Avg. Brinell 10 rails 296 Most of rails show flaking. Three rails show dark shelly spots. Worst rail has four shelly spots 3 in. long	Avg. Brinell 10 rails 300 Five rails turned because of shelling. Others starting to develop shelling
Buchanan, Va., No. 193.0L West of tunnel Curvature 6° Superelev. 3¾ in. Avg. speed 40 mph. Laid new Jan. 1943	1944 45.4 1945 82.0	Avg. Brinell 10 rails 269 Very slight flow	Avg. Brinell 10 rails 294 Most rails flaking. Three rails starting to develop small dark shelly spots	Avg. Brinell 10 rails 299 Five rails have heavy shelling Other light shelling
Hinton, W. Va., No. 350.4L Little Bend Tunnel Curvature 3° 36′ Superelev. 3 in. Speed 60 mph. pass. 35 mph. fgt. Laid new April 1943	1944 29.9 1945 60.0	Avg. Brinell 10 rails 273 Some bead on gage side	Avg. Brinell 10 rails 305 Practically all rails show flaking, but no dark shelly spots	Avg. Brinell 10 rails 306 Most rails show heavy flaking but no shelling
Sewell, W. Va., No. 397.8L At water tank Curvature 3° 30′ Superelev. 3⅜ in. Speed 50 mph. pass. 35 mph. fgt. Laid new May 1943	1944 14.4 1945 28.0	Avg. Brinell 10 rails 276 Good condition	Avg. Brinell 10 rails 302 Rails in good condition	Avg. Brinell 10 rails 310 Rails in good condition

Observations of Newly Laid Rails in Test Track Curves

In 1943, the rails on four curves on the Chesapeake & Ohio where shelling had previously developed were replaced with new carbon steel rails. Each year these rails have been examined by the writer, with the railway's representative, L. H. Roden. Brinell hardness tests have been made each year. Table 2 summarizes the observations

for three years. It will be noted that one curve developed shelling to such an extent that the rails had to be turned in a little more than two years. In another curve which carries the same traffic, five rails have suffered heavy shelling. The other two curves are not as sharp and do not receive as much traffic, and to date no shelling has developed.

During the inspection of shelly rails on the Norfolk & Western in June 1945, Brinell hardness tests were made on three-percent chromium rails in three different curves. Ten rails which had been in track on two curves only two months had an average Brinell hardness of 363, while seven rails in the third curve which had been in track ten months had an average Brinell hardness of 411. It was also observed that the three-percent chromium rails did not contain hard streaks caused by wheel slippage as were observed on many standard carbon steel rails in the same track.

Report on Assignment 12

Investigate Recent Developments Affecting Rail Design

C. B. Bronson (chairman, subcommittee), W. C. Barnes, C. B. Bryant, W. J. Burton, H. R. Clarke, C. J. Code, G. F. Hand, F. S. Hewes, L. S. Jeffords, G. M. Magee, Ray McBrian, C. E. Morgan, W. H. Penfield, F. S. Schwinn, J. C. Wallace, Louis Yager.

This is a progress report and is presented as information.

A year ago, the subcommittee presented six reports on the various phases of the work carried out during that year. The outline of procedure of the investigation as stated two years ago consists of three main phases, as follows:

1. Obtain such additional field measurements as necessary and analyze them to determine the range of stresses and frequency of their occurrence throughout the webs of both 112-lb. and 131-lb. RE rail sections.

2. Determine to what extent the stress range, as found in the present rail sections, can be lowered by revisions or modification of the web or other elements of the rail cross section.

3. Determine by laboratory investigation the fatigue strength of steel in the rail web, including the effect of mill scale, stamped and rolled letters, corrosion, etc., with particular regard to the range of stress that is encountered in service conditions.

The work carried out during the past year is subdivided as follows:

(a) A preliminary report of the tests conducted in 1945 on the tracks of the Norfolk & Western Railway to determine the range of stresses and frequency of their occurrence in 131-lb. RE rail is presented in Appendix 12a, Stress Measurements on 131-lb. RE Rail in Tangent and in a 6-Deg. Curve under Regular Traffic—Norfolk & Western Railway—1945.

(b) A report of rail study sections designed to incorporate modifications that might be expected to lower the stresses from those found in the sections now in use, and laboratory tests so controlled as to permit direct comparison of stresses obtained with these rail sections is presented in Appendix 12-b under the title, Rail Design Study and Tests on Modified Rail Sections—1945.

(c) A report of the fatigue strength of rail web specimens as conducted at the Talbot Laboratory, University of Illinois, is presented as Appendix 12-c with the title, Fatigue Tests of Rail Webs by R. S. Jensen.

Appendix 12-a

Stress Measurements on 131-lb. RE Rail in Tangent and in a 6-Deg. Curve Under Regular Traffic—Norfolk & Western Railway—1945

During the summer of 1945 extensive stress measurements were made on 131-lb. RE rail in straight and curved track on the Norfolk & Western Railway. That portion of the data pertaining to shelly rail studies is presented in Appendix 11-a of this report.

Later, when the additional data are analyzed, they will afford further information with regard to Part 1 of this investigation, namely to obtain such additional field measurements as necessary and analyze them to determine the range of stresses and frequency of their occurrence throughout the webs of both 112-lb. and 131-lb. RE rail sections.

The data when presented, will augment information already reported in AREA Proceedings, Vol. 46, 1945, page 692; Vol. 45, 1944, page 470; Vol. 44, 1943, page m5; and Vol. 42, 1941, page 758.

Appendix 12-b

Rail Design Study and Tests on Modified Rail Sections—1945

To obtain further information with regard to Part 2 of the investigation, namely, to determine to what extent the stress range, as found in the present rail sections, can be lowered by revisions or modifications of the web or other elements of the rail cross section, additional study designs were prepared and tests made with the support and loading conditions so controlled as to permit a direct comparison of the stresses obtained with the rail sections of various designs.

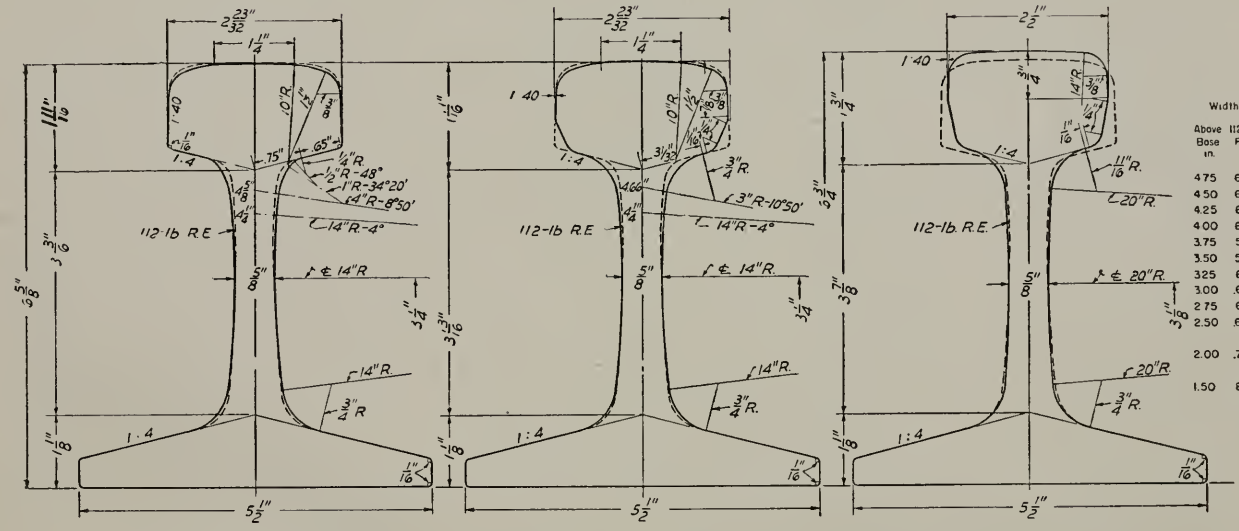
The courtesy extended by Northwestern Technological Institute in permitting the use of its laboratory facilities for the tests by the research staff of the Engineering Division, Association of American Railroads was particularly helpful.

Randon Ferguson, electrical engineer, and M. F. Smucker, assistant electrical engineer, conducted the laboratory tests. The investigation has been assigned to the Engineering Division research staff and is directed by E. E. Cress, assistant research engineer, under the general supervision of G. M. Magee, research engineer. Funds are provided by the Association of American Railroads.

The Six Test Rails

The rail designs used for test were: (1) The 112-lb. RE; (2) the 114-lb. Study Section G; (3) the 113-lb. Study Section H; (4) the 112-lb. TR (torsion resisting rail) of the Chicago, Burlington & Quincy Railroad; (5) the 131-lb. RE; and (6) the 132-lb. Study Section U. Designs (1), (4) and (5) were the ordinary rolled sections. Designs (2), (3) and (6) were machine planed to size from rails of a heavier original section. A 7-ft. 6-in. length of rail was used for each test rail. Dimensions of four of the rail sections are shown in Figs. 1 and 2. The properties of the rails are given in Table 1.

The basis used by the research staff for designing Study Sections G and U is as follows. The magnitude of the measured maximum localized stresses in the upper web fillet of a standard type rail under an eccentrically applied load have been found to be inversely proportional to the length of the fillet radius. For the 112-lb. RE rail with an upper fillet radius of $\frac{3}{8}$ in. length, the fillet stresses are higher than they would be in the same type of rail with a fillet radius of $\frac{5}{8}$ in. or longer. However, it is impossible in the upper fillet to introduce a simple curve with a radius long enough to reduce the fillet stress materially and still leave the required length of straight portion on the under



Widths of Webs in Inches

Above Base in.	112-lb. RE	Study Sect. G	Study Sect. H	C.B.&Q. 112-lb. T.R.
4.75	.694	.865	.885	.800
4.50	.650	.750	.760	.719
4.25	.620	.697	.697	.688
4.00	.600	.665	.665	.659
3.75	.594	.643	.643	.645
3.50	.596	.630	.630	.633
3.25	.606	.625	.625	.627
3.00	.620	.630	.630	.627
2.75	.638	.643	.643	.633
2.50	.662	.665	.665	.645
2.00	.728	.737	.737	.688
1.50	.816	.845	.845	.763

Fig. 1.—Modified Designs of 112-lb. RE Rail Used in Tests.

TABLE 1

Properties of Rails

Rail Section	Area sq. in.	Weight lb.per yd.	I_4 in.^{4}	$^3I/c$ in.^{3} base	$^3I/c$ in.^{3} head	N. A. in.to base
112-lb. RE	11.01	112.3	65.5	21.8	18.1	3.00
Study G	11.20	114.2	65.5	22.0	18.0	2.98
Study H	11.12	113.4	65.0	21.9	17.8	2.97
112-lb. TR	11.01	112.3	67.0	22.3	17.9	3.01
131-lb. RE	12.82	130.8	88.5	27.6	22.6	3.20
Study U	12.95	132.1	88.2	27.6	22.5	3.20

side of the rail head to provide for head-contact joint bars. It is further known that the stress in the upper portion of a standard upper fillet is moderate in value. The stress increases in magnitude at positions further down on the fillet radius arc, until at mid-arc the stress may become high in a short length radius. Below mid-arc the stress in a sharp fillet remains high down to its connection with the upper web and in the adjoining portion of the web.

By the use of a spiraled or compound curvature in the web fillet surface, a sharp curvature may be used in the top portion where the stress is low, thus permitting the radius of curvature to be increased lower down in the fillet, and effecting a reduction in the localized stress in the fillet.

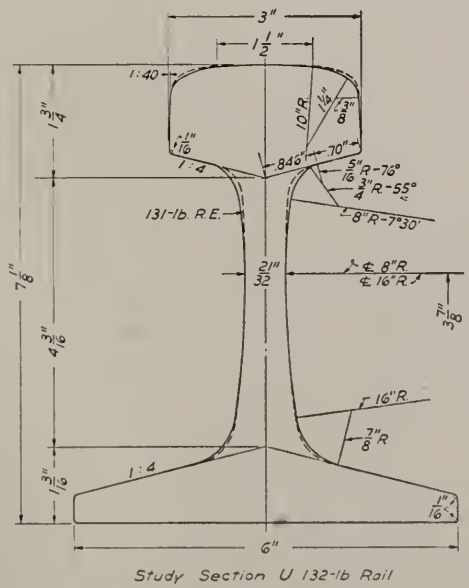


Fig. 2.—Modified Design of 131-lb. RE Rail Used in Tests.

In the two study sections G and U it has been necessary to decrease the straight portion on the under side of the head by 0.07 and 0.08 in. from the standard sections. It is thought that tbis will still provide sufficient contact surface for head-contact bars. The distance from the point of fillet curvature to the extreme edge of the lower portion of the head is as follows for several rail designs with which head-contact type bars have been successfully used:

90-lb. RA–A	0.67 in.	127-lb. NYC	0.73 in.
100-lb. RE	0.72	131-lb. RE	0.78
110-lb. GN	0.62	136-lb. L.V.	0.65
112-lb. RE	0.72	152-lb. P.S.	0.72
114-lb. Study G	0.65	132-lb. Study U	0.70

Study Section H was designed with a simple upper fillet radius of ¾ in. with the expectation that the upper fillet stresses would be reduced under an eccentrically applied load. The upper portion of the long fillet radius extends so far out on the under side of the rail head that only headfree bars can be used. The lower outer corners of the head may be removed as shown by the full lines in Fig. 1, or the conventional head as shown by the dashed lines may be used.

Study Section V (133-lb.) has been designed with a simple upper fillet radius of ⅞ in. It has the exact dimensions of Study U, except that the simple upper fillet radius of ⅞ in. is substituted in that design. A length of this rail is being planed at the present time.

The running surfaces of the heads of the study section rails have been slightly changed to a contour that might delay rail shelling to some extent. It is expected that the mills should experience little or no difficulty in the rolling of these sections. The height, width of head and base and fishing height for these study sections are the same as for the corresponding standard sections.

Test Rail Assembly

Twenty-eight SR–4 wire gages ¼ in. long were attached at one cross section at midlength of each test rail of 7-ft. 6-in. length. This length of test rail is sufficient because the portion of the rail resisting direct load is limited to a length extending about 5 in. each way from the load, and it has also been shown that with an eccentrically applied load with or without lateral component, the length of section resisting localized bending lies within 24 in. each way from the load. A mat of Celotex 2 in. thick was laid on the large base of the testing machine. Five sawn ties 18 in. long with tie plates attached were placed on the mat at 20-in. spacing. A test rail was put in place with the gages directly over the middle of the central tie plate. A test load of 40,000 lb. was applied directly over the gages at controlled positions across the rail head through a contact bearing ⅜ in. wide and 1 in. long. Loadings were made with the load concentrated at the middle of the rail head and at eccentric positions ¾ in. each way from the middle. An attempt was made to load the rail 1 in. from the middle of the head but the placing of the loading block at this position could not be repeated with enough accuracy to warrant tests with this amount of eccentricity of loading. Fig. 3 shows views of a test rail assembly.

This laboratory assembly closely approximates ideal track conditions in the method of loading and in the distribution of upward tie reactions. It had been previously determined that the Celotex mat was elastic within the load limit used. The rail support corresponds to a modulus of elasticity of rail support, u, of about 1600 lb. per in. per in.

A complete set of loadings was made for a test rail described above with flat seated tie plates with 1 in 40 cant. A second set of loadings was made with circular rolled

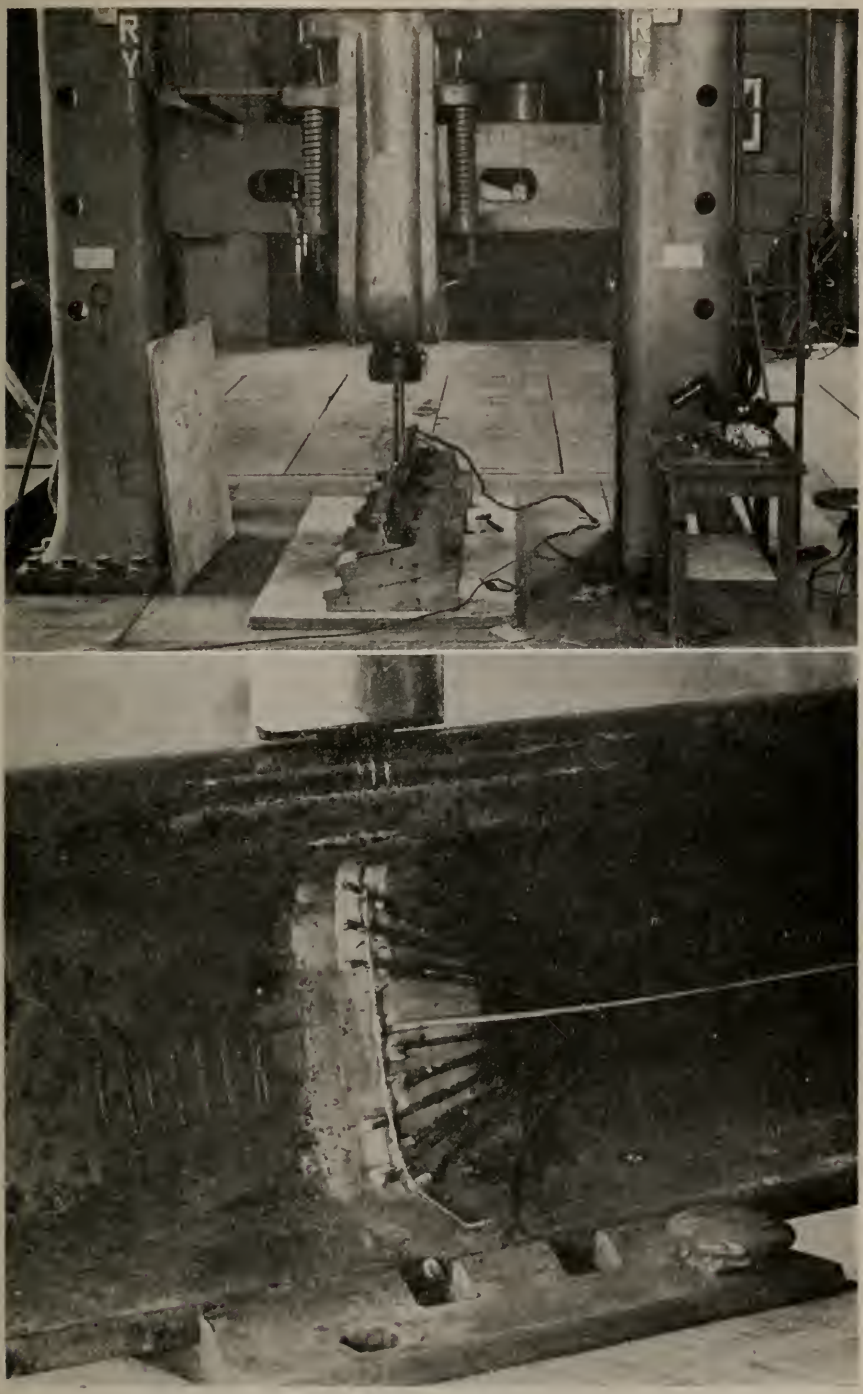


Fig. 3.—Test Rail Assembly and Arrangement of Test Gages on a Rail.

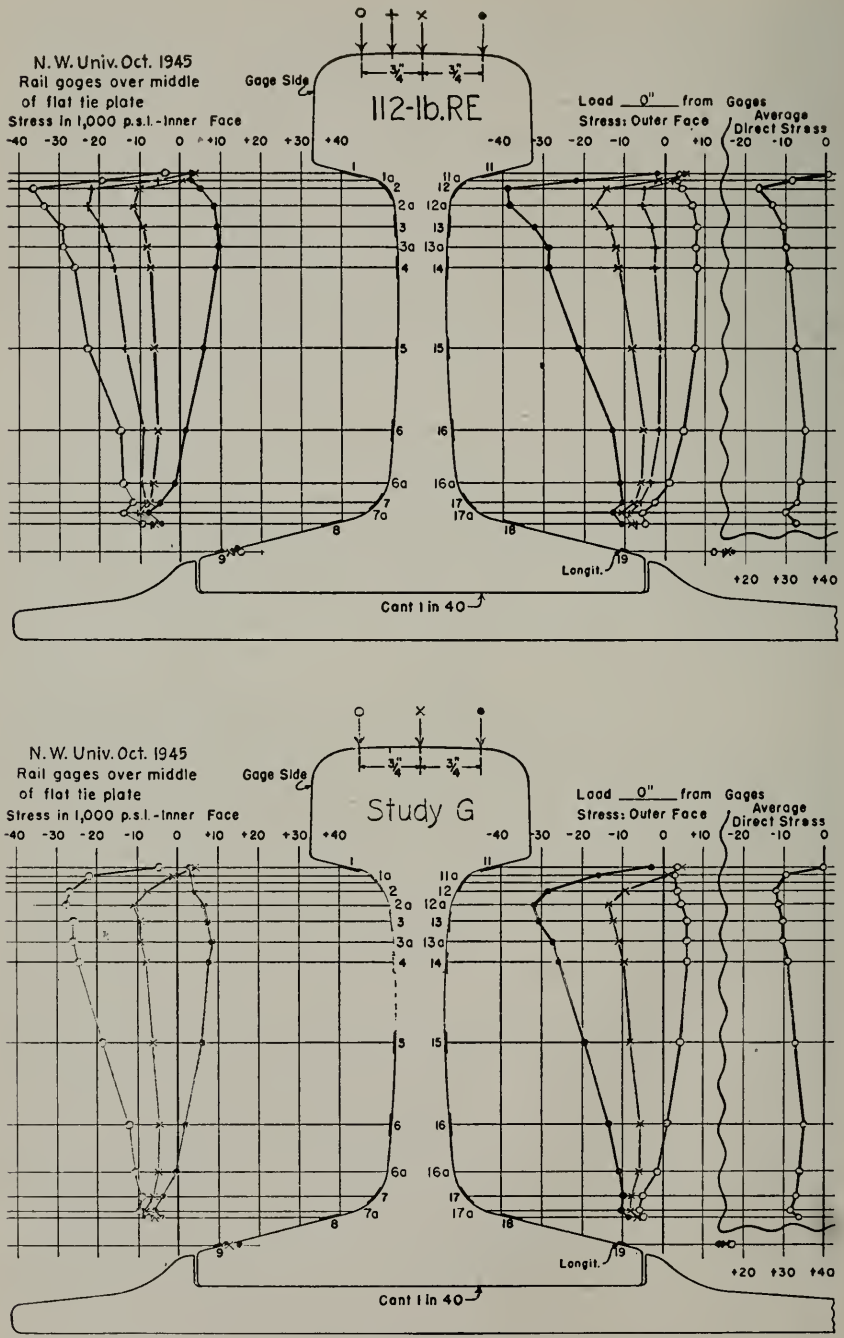


Fig. 4.—Measured Stresses in 112-lb. RE Rail and in 114-lb. Study G Rail over Middle of a Flat Seat Tie Plate for Static Vertical Load of 40,000 lb.—Controlled Loading Conditions as Indicated on Rail Head.

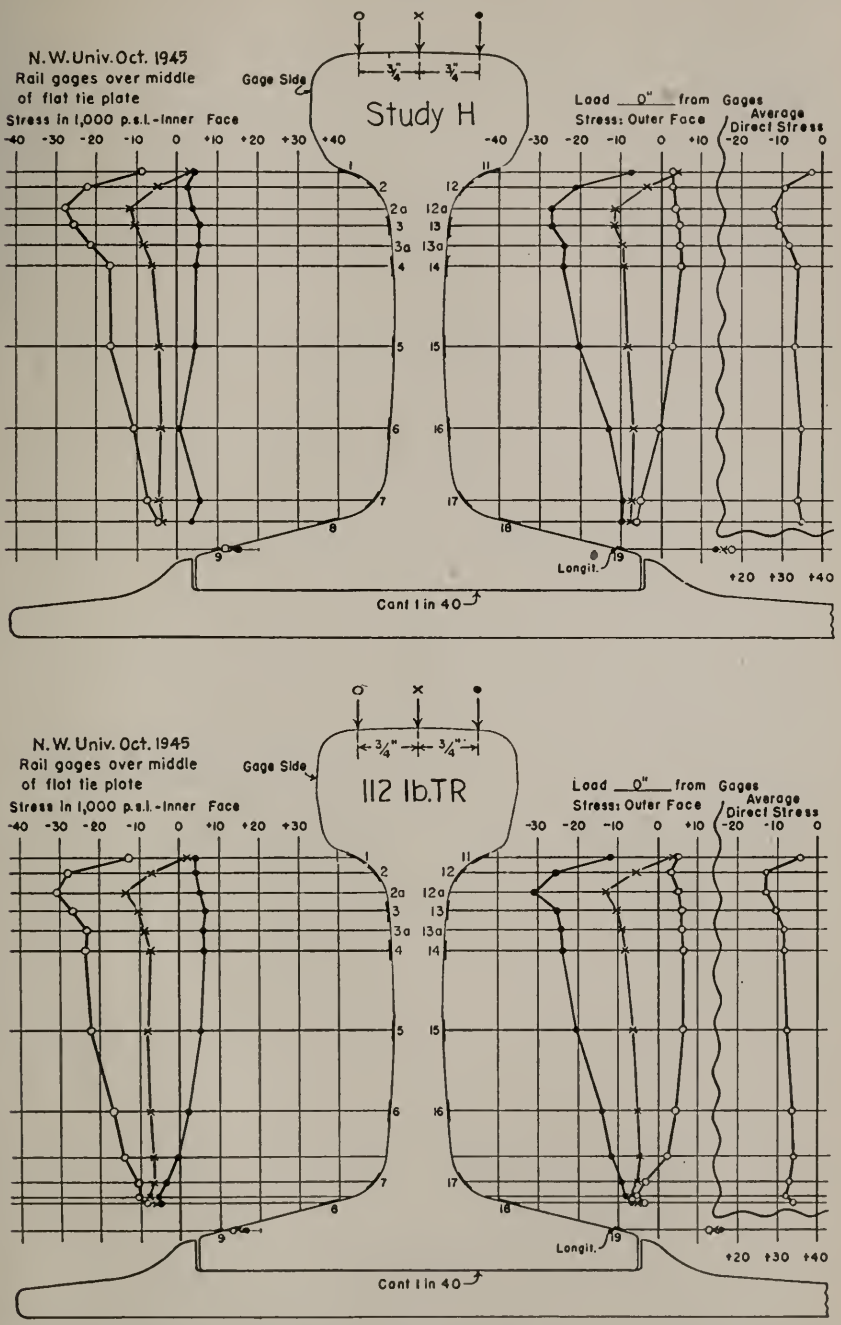


Fig. 5.—Measured Stresses in 113-lb. Study H Rail and in 112-lb. TR Rail over Middle of a Flat Seat Tie Plate for Static Vertical Load of 40,000 lb.—Controlled Loading Conditions as Indicated on Rail Head.

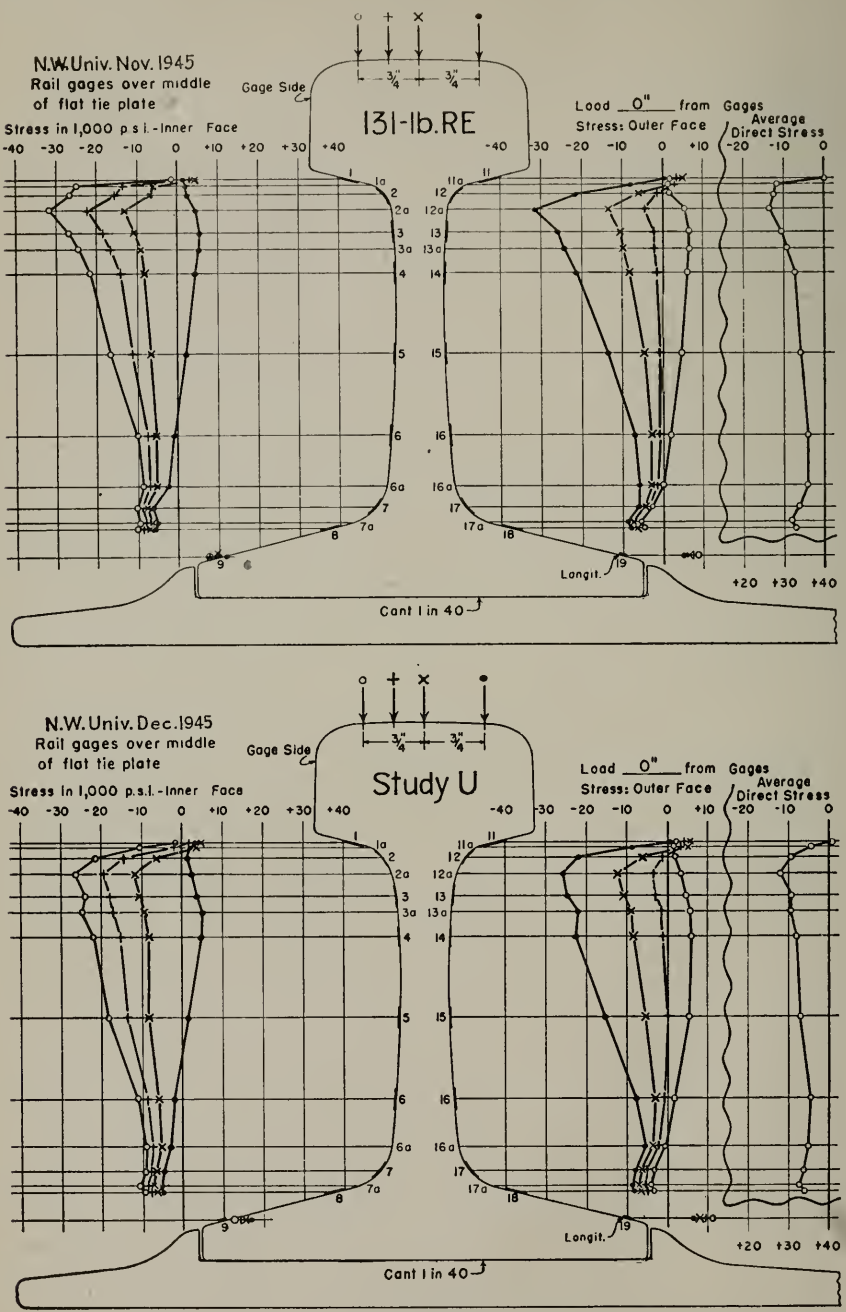


Fig. 6.—Measured Stresses in 131-lb. RE Rail and in 132-lb. Study U Rail over Middle of a Flat Seat Tie Plate for Static Vertical Load of 40,000 lb.—Controlled Loading Conditions as Indicated on Rail Head.

crown tie plates with 1 in 40 cant. Third and fourth sets of loadings were made with these two types of tie plates and the same assembly except that tapered wooden blocks to give an outward slope of 1 in 4 (less the cant of the tie plates) were inserted under the five ties. This arrangement produced a lateral loading component on the rail of 9000 lb. toward the outer shoulder of the tie plates in combination with the vertical loading of 40,000 lb. to simulate the loading condition to which the rail is subjected in curved track.

The tests were planned so that all six of the rails could be placed in the assembly in the testing machine one after the other, and each subjected to the same loading conditions so that direct comparisons could be made in the magnitude and distribution of their stresses.

Three stress gages were located in an upper web fillet of each rail (gages 1a, 2 and 2a). Three additional gages were placed on each side of the upper web of each rail at positions 4½, 4¼, and 4 in. above the base for the intermediate weight rails and at 4⅞, 4⅝ and 4¼ in. for the heavy rails (gages 3, 3a and 4). On five of the rails, three gages were placed in each lower web fillet in an effort to determine any change in stress that might be due to the differences in lower fillet radii.

Two gages (9 and 19) were placed longitudinally on the upper side of the flanges of the rail base to measure the longitudinal bending strain in the rail and the concentrated strain caused by the tie plate pressure. All gages except these two measure the strain around the periphery of the rail cross section, transversely to the rail length.

TABLE 2

Maximum Stresses in Upper Web Fillets and Upper Portion of Webs of Rails with Vertical Loads of 40,000 lb. Applied 3/4 in. Inside and Outside Middle of Rail Head.

Stresses in lb. per sq. in.; - is compression

Rail Section	Upper Fillet				Upper Web			
	Gage Face		Outer Face		Gage Face		Outer Face	
	Over Flat Seated Tie Plates with 1 in 40 Cant							
112-lb. RE	(Ga.2)	-36,700	(12)	-39,400	(3)	-29,700	(13)	-32,200
Study G	(2a)	-28,400	(12a)	-32,300	(3)	-26,600	13)	-30,300
Study H	(2a)	-27,700	(12a)	-27,600	(3)	-25,600	(13)	-27,600
112-lb. TR	(2a)	-30,700	(12a)	-30,600	(3)	-27,200	(13)	-26,000
131-lb. RE	(2a)	-31,800	(12a)	-31,200	(3)	-26,700	(13)	-25,500
Study U	(2a)	-27,000	(12a)	-26,100	(3)	-24,500	(13)	-24,800
	Over Rolled Crown Tie Plates with 1 in 40 Cant							
112-lb. RE	(Ga.2)	-36,700	(12)	-38,700	(3)	-30,400	(13)	-31,300
Study G	(2a)	-29,700	(12a)	-32,400	(3)	-27,800	(13)	-30,600
Study H	(2a)	-28,800	(12a)	-27,500	(3)	-27,800	(13)	-27,800
112-lb. TR	(2a)	-31,500	(12a)	-30,800	(3)	-27,900	(13)	-26,000
131-lb. RE	(2a)	-32,000	(12a)	-31,200	(3)	-27,000	(13)	-26,100
Study U	(2a)	-26,800	(12a)	-25,800	(3)	-24,500	(13)	-24,500

Results of Tests

In Figs. 4, 5 and 6 are plotted the measured stresses at the various gages on the six test rails with the vertical load of 40,000 lb. applied at different positions as indicated on each rail head. For the ¾-in. eccentrically applied load positions, repeat loadings were made and the stresses for the two check loadings were averaged. It was seldom that the stress for an individual gage varied as much as 1000 lb. per sq. in. for the two loadings. The stress measurements were made with the rails supported on both flat seated and circular rolled crown tie plates. However, only the stresses with the rail on the flat seated tie plates are shown in the diagrams. The stresses in the upper fillets and upper portion of the rail web were substantially the same for the two types of tie plates. The stresses in the lower outer fillet and in the outer flange of the rail base were considerably higher over the rolled crown plate, but this difference is better illustrated in the stress diagrams shown later for the combined vertical and lateral loading of the rail. Maximum stresses recorded in the upper fillets and upper portion of the webs of the six rails are given in Table 2.

Figs. 7, 8 and 9 show the measured stresses at the same gage locations for the six test rails with a 9000-lb. outward load in combination with the 40,000-lb. vertical load. This loading was accomplished by placing wooden blocks, tapered 1 in 4, under the five ties to tilt the rail outwardly, see Fig. 3. Each rail was tested with the combined load applied directly over the middle of the rail head and also with the same load applied with an eccentricity of ¾ in. towards the gage side. The solid lines in the diagrams represent the measured stresses with the rail on the flat seated tie plates; the dashed lines, on the rolled crown tie plates. In the lower right hand side of these diagrams, the longitudinal tensile stress in gage 19 is plotted; for all rails, the high pair of plotted stresses is directly over the rolled crown tie plates and the moderate pair is over the flat seated tie plates.

It will be observed in Figs. 4 to 9, inclusive, that for a given eccentricity of loading, the stresses in the upper fillets and upper portion of the web are the same for all practical purposes irrespective of whether the vertical load is combined with a lateral load or acts alone; also, whether the rail is supported on a flat seated or rolled crown tie plate. The important factors then which produce high stresses in the upper fillets and upper portion of the web are the magnitude of the vertical load and the amount of eccentricity.

For the same amount and eccentricity of loading, it will be seen from Table 2 that the average maximum measured stresses in the upper fillets compare as follows:

Rail Section	*Stress (lb. per sq. in.)*	*Ratio (percent)*
112-lb. RE	37,900	100
Study G	30,700	81*
Study H	27,900	74
112-lb. TR	30,900	82
131-lb. RE	31,600	83
Study U	26,400	70
Study V	25,800	68

* The outer upper web fillet of Study G rail was not planed quite up to full section; had it been, this ratio might have been reduced slightly.

It is thus apparent that Study Sections G and H and the 112-lb. TR rail effect a considerable reduction in upper fillet stresses relative to the 112-lb. RE rail, and Study Section U relative to the 131-lb. RE rail. In this comparison all percentages are shown relative to the 112-lb. RE rail. Actually, in track the benefit of the two heavier sections would probably be somewhat less than indicated due to the wider head and probable

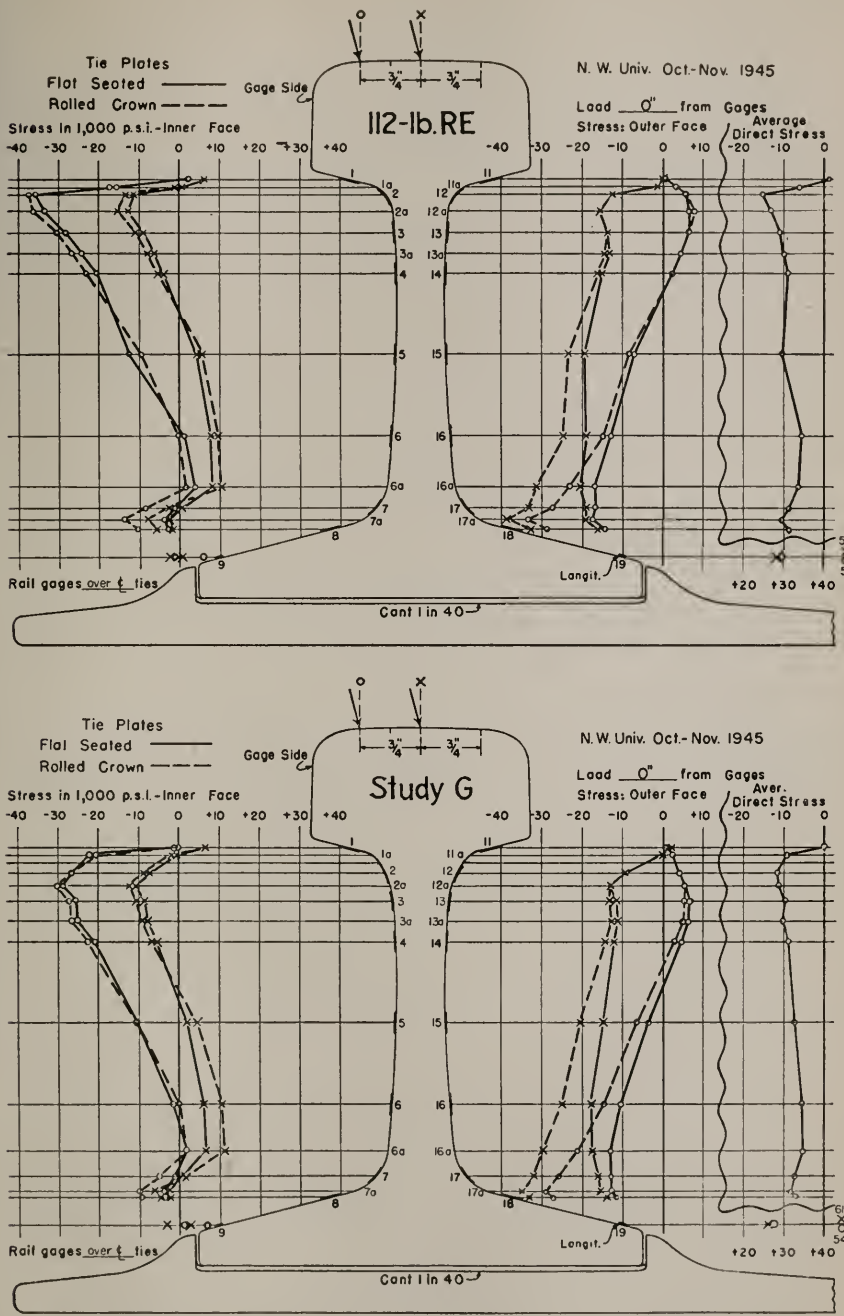


Fig. 7.—Measured Stresses in 112-lb. RE Rail and in 114-lb. Study G Rail over Middle of Flat Seat and Rolled Crown Tie Plates for Vertical Load of 40,000 lb. Combined with Lateral Load of 9000 lb.—Controlled Loading Conditions as Indicated on Rail Head.

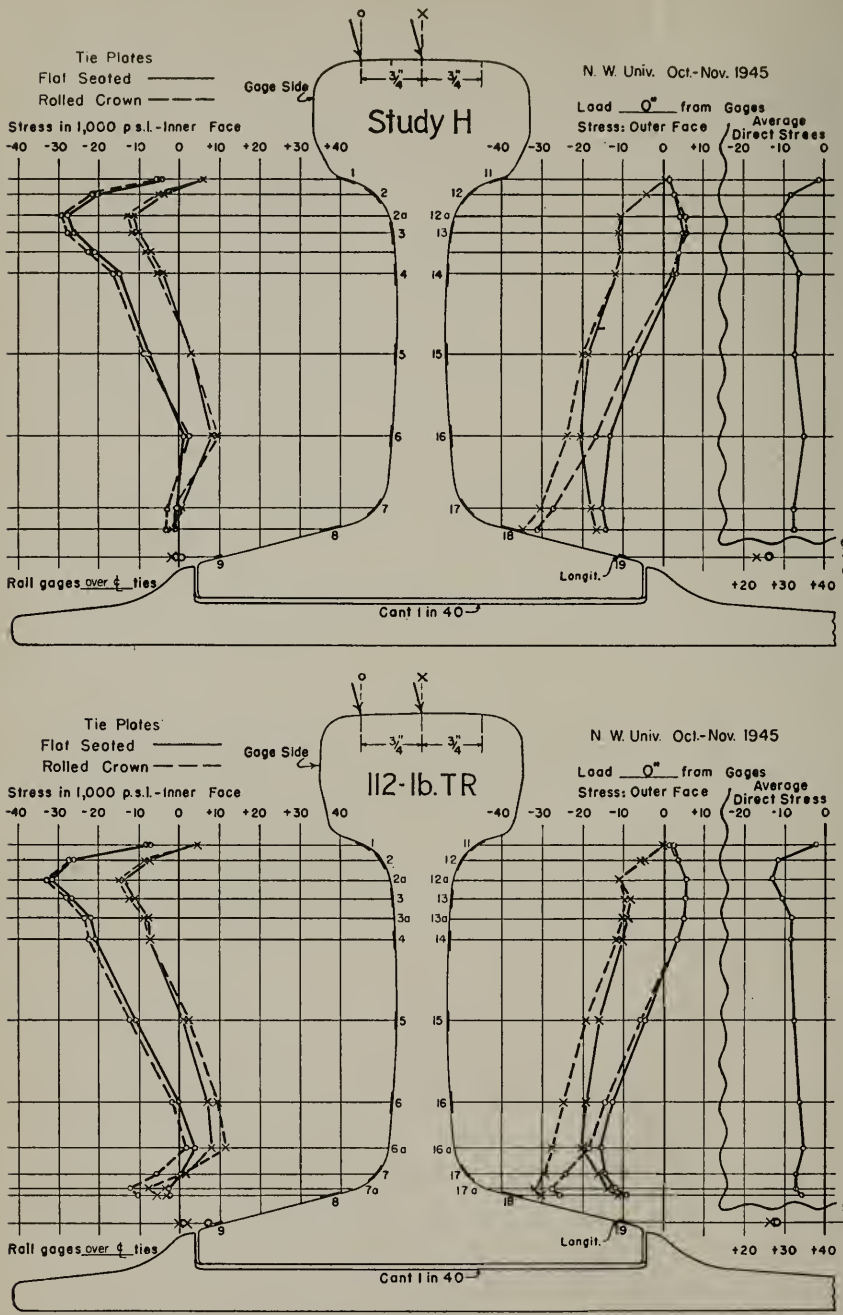


Fig. 8.—Measured Stresses in 113-lb. Study H Rail and in 112-lb. TR Rail over Middle of Flat Seat and Rolled Crown Tie Plates for Vertical Load of 40,000 lb. Combined with Lateral Load of 9000 lb.—Controlled Loading Conditions as Indicated on Rail Head.

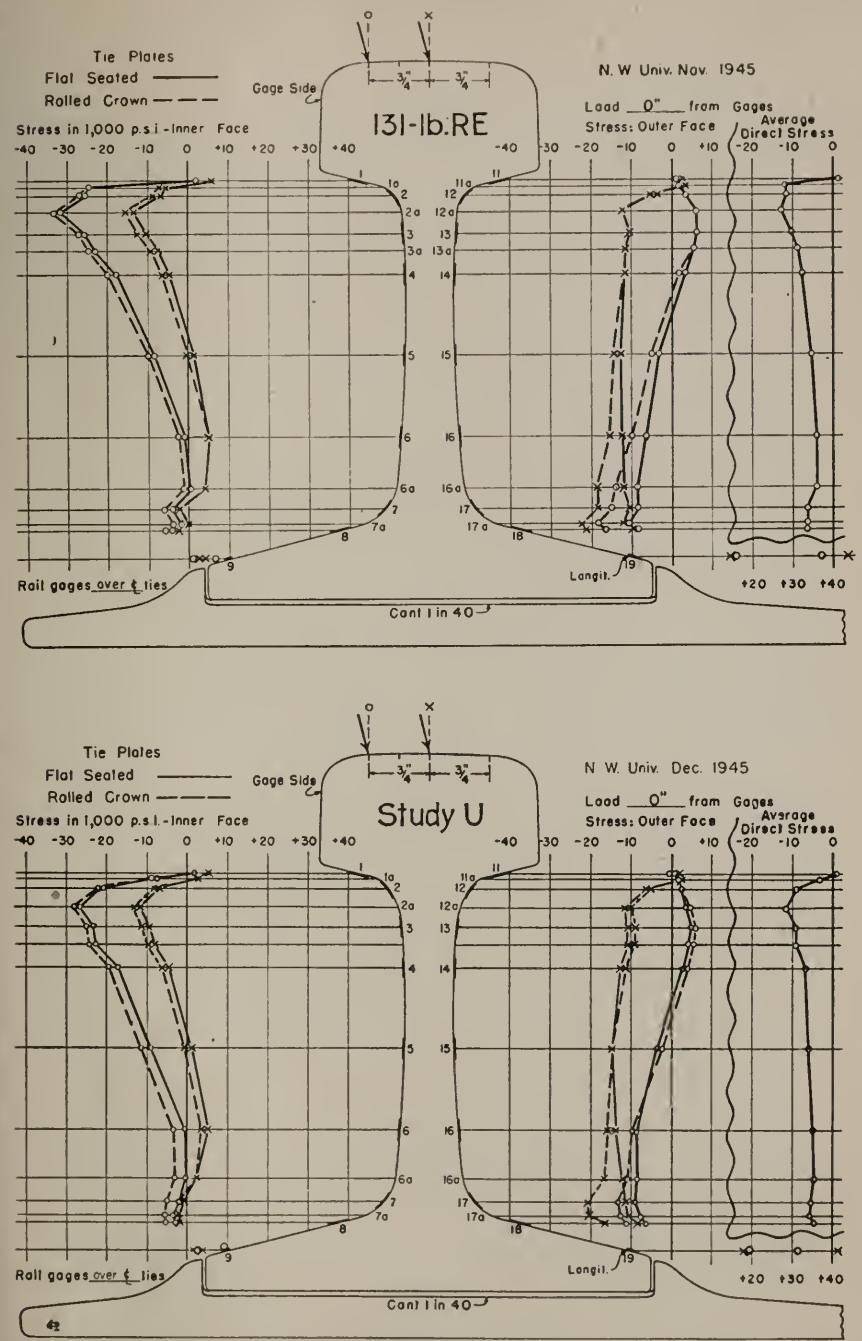


Fig. 9.—Measured Stresses in 131-lb. RE Rail and in 132-lb. Study U Rail over Middle of Flat Seat and Rolled Crown Tie Plates for Vertical Load of 40,000 lb. Combined with Lateral Load of 9000 lb.—Controlled Loading Conditions as Indicated on Rail Head.

increased eccentricity of loading. For the 112-lb. TR rail the benefit would probably be somewhat greater than shown due to its narrower head.

During the time of printing of this report, the tests on 133-lb. Study Section V were completed. This section has the exact dimensions of Study U, except that a single upper fillet radius of 7/8 in. is substituted in that design. This section is usable only with head-free type joint bars. With the eccentric load of 40,000 lb. placed 3/4 in. from the middle of the rail head, the average maximum stress in the upper web fillet was 25,800 lb. per sq. in. compression. This maximum value was recorded in the lower portion of the fillet at gage lines 2a–12a. The machined fillet radius in this rail length at this point was slightly sharp, which may have raised the measured maximum stress slightly. Study V shows only a slight reduction from the maximum fillet stresses measured in Study U. It might be thought that an eccentric load at the gage corner of the rail head might change the position of the maximum stress in a fillet from that found with the load at 3/4 in. from the middle of the head. Study V was also tested with a load of 40,000 lb. applied at the gage corner of the head (1 1/4 in. inside the middle of the head). This greater eccentricity of loading did not change the position of the maximum stress in the fillet. It raised the proportionate values of the stresses high up in the fillet to some extent. The compressive stresses in the upper web fillet gage lines 1, 1a, 2 and 2a were 10,000, 21,000, 29,700 and 37,800 lb. per sq. in., respectively for 1 1/4 in. eccentricity.

The magnitude of the upper fillet stress is inversely proportional to the length of the fillet radius. The stress in the upper portion of the fillet is moderate in value; it increases until at mid-arc the stress becomes high in a short length radius and remains high down to the connection with the web. In fillets with 1/2 in. or longer radii, the maximum stress occurs well below mid-arc and remains high down to the connection with the web. As the 131-lb. RE rail has an upper fillet radius of 1/2 in., it is more difficult to reduce the fillet stresses by design modification in as great a ratio as for modifications of the 112-lb. RE rail with a fillet radius of 3/8 in.

Maximum upper fillet stresses as high as 75,000 lb. per sq. in. compression have been recorded in both the 112- and 131-lb. RE rails in the inner rail of a sharp curve under a very occasional driving wheel. It might be expected that comparable fillet stresses in Study Sections G, H and U and 112-lb. TR rails would be reduced to about 55,000 to 63,000 lb. per sq. in.

The study section rails have the upper portion of their webs thickened by about 1/16 in. A stress reduction from the standard section of about 10 percent at this position is effected. A greater reduction is desirable but no effective way of achieving it is known. In the Proviso tests for other 112–115-lb. rails, it was found that a web thickness of more than 3/4 in. at a height 4 1/2 in. above the base had but little advantage in reducing stresses in the upper portion of the web.

The modification of the lower portion of the rail web of the study sections consisted of a slight thickening of the web towards the lower fillet and an increase in the length of lower fillet radius from 5/8 in. for the 112-lb. RE to 3/4 in., and from 3/4 in. for the 131-lb. RE to 7/8 in. These modifications are only important when the rail is subjected to high lateral loads in conjunction with vertical loads.

As shown in Table 3, the stresses in the 5/8-in. radius lower outer fillet of the 112-lb. RE rail are about 15 percent higher than comparable stresses in the 3/4-in. fillets of Study Sections G and H and the 112-lb. TR rail. The 7/8-in. radius fillet of Study Section U also shows an advantage over the 3/4-in. radius fillet of the 131-lb. RE rail. It is noted that the lower portions of the two heavy rails are much stiffer than are the intermediate weight rails.

TABLE 3

Maximum Stresses in Lower Web Fillet and Longitudinally along Base of Rails Directly over Middle of Tie Plates for Vertical Load of 40,000 lb. Combined with Lateral Load of 9,000 lb. Applied at 3/4 in. Inside Middle or at Middle of Rail Head.

Stresses in lb.per sq.in.; - is compression; + is tension.

Tie Plate	Lower Fillet, Gage 17a		Rail Base, Gage 19	
	Flat Seated	Rolled Crown	Flat Seated	Rolled Crown
Rail Section				
112-lb. RE	- 19,700	- 39,100	+ 29,900	+ 54,100
Study G	- 16,200	- 35,100	+ 27,000	+ 60,800
Study H	- 18,000	- 33,300	+ 26,400	+ 60,700
112-lb. TR	- 16,700	- 32,100	+ 28,100	+ 55,100
131-lb. RE	- 11,400	- 22,800	+ 15,300	+ 43,700
Study U	- 10,500	- 20,600	+ 19,500	+ 40,700

As pointed out in last year's report, the use of rolled crown tie plates greatly increases the localized stresses in the lower web fillets and outer portion of the base flanges over the tie plate bearing. Table 3 shows very high tensile stresses on the outer flange of the rail bases directly over the rolled crown tie plate; comparable stresses are cut in half to a moderate value over the flat seated tie plate.

Conclusions

These tests have demonstrated what can be accomplished in lowering localized stresses in the rail fillets and web by revisions in the design of the rail section. In the design of upper web fillets, either a simple long fillet radius (adaptable only with head-free joint bars) or a spiraled or compound curvature with long lower radius (adaptable with either headfree or head-contact joint bars) will decrease the maximum fillet stresses.

These data are given as information at this time and further consideration is being given to correlating them with the data on the fatigue strength of the rail web and the frequency of occurrence of stresses in track to determine what modifications in design, if any, should be recommended.

Appendix 12-c

Fatigue Tests of Rail Webs

By R. S. Jensen

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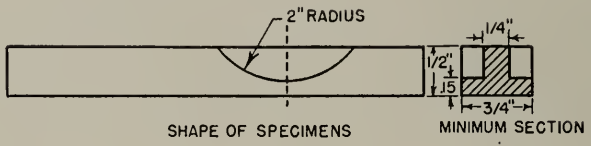
University of Illinois

Because of the difficulty encountered in trying to break the web of a full-sized section of rail in the rolling load machine, as reported last year* it was decided to use specimens cut from the rail and to test these specimens in smaller fatigue machines. This procedure also has the advantage of effecting some increase in the speed of testing.

* Proceedings, Vol. 46, 1945, pp. 744–749 and University of Illinois Engr. Exp. Station Reprint Series No. 32, pp. 22–27.



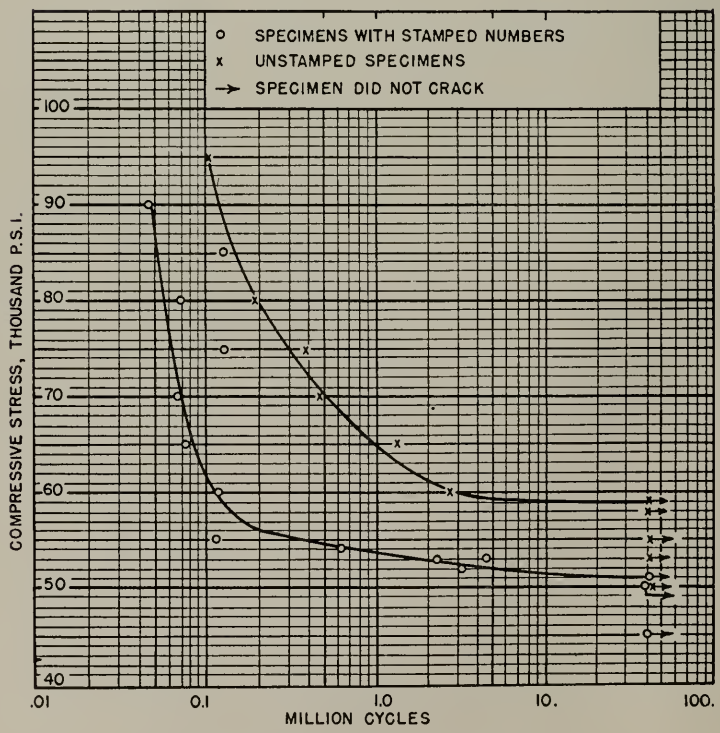


Fig. 1.—Fatigue Tests of Rail Web Specimens.

Fig. 2.—Specimens Used in Fatigue Tests of Rail Webs.
All specimens etched in hot 50-percent hydrochloric acid.
(a) Specimen showing several fatigue cracks.
(b) Specimen with light stamped 3.
(c) Specimen with heavy stamped 3.
(d) Specimen completely broken.

Two vibratory type machines, designed by Professor H. F. Moore, and previously built at the university laboratory were used for these tests.

The shape of the specimens is shown in Fig. 1. In order to simulate conditions in the field as nearly as possible, and to insure a compressive fatigue failure, the specimens were designed with a T-shaped minimum cross section. The ¼-in. wide top surface was left in the as-rolled condition, and a small amount of metal was removed from the opposite side, which left very nearly a full-sized web in thickness. This shape limited the maximum tensile stress developed on the ¾-in. wide machined surface to only 57 percent of the maximum compressive stress on the ¼-in. as-rolled surface and insured failure on the compressive side. Since all the fatigue failures were in compression, the cracks progressed quite slowly and the criterion of failure was taken to be the number of cycles when the crack could be first detected. Four specimens used in these tests are shown in Fig. 2.

In all tests a constant ratio of compressive to tensile stress was maintained, the bending stress on the top side ranging from a maximum compressive stress to a tensile stress 20 percent as great. This range ratio of —0.20 was based on information supplied by G. M. Magee, research engineer, AAR, as a common range ratio of web stresses found in the field.

The specimens were cut from two sections of 112-lb. RE rail supplied by the Ensley mill at Birmingham, Ala. To date, 11 unstamped specimens and 15 specimens with stamped numbers have been tested, the depth of stamping varying from 0.014 in. to 0.060 in. The calculated bending stress for these specimens was based on the full thickness of the specimen.

As would be expected, some scatter is evident with the stamped specimens, however, the fatigue curves of Fig. 1 show that reduced fatigue strength results from stamping. These data would indicate an endurance limit of approximately 59,000 psi. for unstamped specimens, and 51,000 psi. for stamped specimens at 40 million cycles. At one million cycles, the reduction in fatigue strength for the stamped specimens is slightly over 20 percent.

Although these tests were made on specimens instead of a complete rail section, the stresses were of the same order of magnitude as the web stresses which occur in the field, thus affording a measure of the reduction in fatigue strength of a full-sized web which may be ascribed to the presence of stamped numbers.

Twelfth Progress Report of the Joint Investigation of Failures in Railroad Rails in Service and Their Prevention

Conducted by

The Engineering Experiment Station, University of Illinois

In Cooperation with

The Association of American Railroads

and

The American Iron and Steel Institute

By R. E. Cramer* and R. S. Jensen*

I Introduction

Organization of Research

This report covers three phases of research on railroad rails. The first portion is a final report on service tests of end-hardened rails on the Chesapeake & Ohio Railway at Carey, Ohio. The second part covers the past year's laboratory examination of failed, control-cooled rails to determine the causes of failure. The third part gives some information on the control cooling of three percent chromium and intermediate manganese rails. The work is sponsored and financed jointly by the Association of American Railroads and the American Iron and Steel Institute.

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The sponsors of this work are represented by advisory committees consisting of the following:

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* Special Research Associate Professor and Special Research Associate, Respectively, of Engineering Materials, University of Illinois.
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Acknowledgment.—The writers of this report wish to acknowledge the valuable services of M. C. Moore, mechanician in the laboratory shops and of Proal Judson and Jean Louvier, student assistants, who have helped in the laboratory tests.

II Final Report on Service Tests of End-Hardened Rails on the Chesapeake & Ohio Railway at Carey, Ohio

Test Arrangements

F. M. Graham, assistant engineer of standards, Pennsylvania Railroad, was chairman of Subcommittee 4 on Cause and Prevention of Rail Battering, in April 1939, when the Carey test track was laid. He made arrangements to obtain 800 rails end-hardened by eight different processes and 100 unhardened rails for the tests, and have them laid by the Chesapeake & Ohio Railway at Carey, Ohio. The following is a brief description of the end-hardening processes used.

Methods Used to End-Harden Test Rails

A. Mill End-Hardening Processes

Process 1. Electric induction heating. Warm water quench. End of rail head reheated by electric induction method to 1540 deg. F. in 80 sec. Quenched by an automatically regulated flow of warm water for 30 sec.

Process 2. Gas reheating. Compressed air quench. End of rail head reheated in a portable, refractory lined furnace with gas flame to approximately 1550 deg. F. in 3 min. Quenched with jet of compressed air for 3 min.

Process 3. Quenched from rolling heat with water spray. After leaving the hot saws the rails are allowed to cool to 1500 deg. F. and the ends are quenched by a water spray for 30 to 35 sec. When the body of the rail has cooled to 1000 deg. F. a small cover is placed over the end of the rail.

Process 6. Brunorized rails. Compressed air quench. Rails are cooled in air from the rolling heat to approximately 1000 deg. F., then held at this temperature in gas heated, insulated boxes for 3 hours or more. The entire rail is then reheated in a gas fired furnace to about 1500 deg. F. in 20 to 30 min. Next the ends of the rail heads are quenched with jets of compressed air for approximately 2½ min.

B. Field End-Hardening Processes

Process 7. Oxweld oxyacetylene burners. Self quench. Both rail ends of a joint are heated at the same time by three oxyacetylene tips over each rail. The surface of the rail is heated to 1550 deg. F. in 18 to 24 sec. Quench is by conduction of the cold metal under the heated zone.

TABLE 1.—AVERAGE BATTER IN THOUSANDTHS

Traffic Million Tons		*June 1939 1.85*	*April 1940 38.0*	*April 1941 77.0*	*April 1942 125.0*	*April 1943 174.5*	*May 1944 222.5*	*May 1945 267.3*
Process 7	Lv.	5.62	9.24	10.3	10.8	13.1	13.1	15.3
Oxweld	Rec.	7.96	6.66	3.9	4.1	5.4	6.1	8.6
	Av.	6.79	7.95	7.1	7.45	9.3	9.6	11.9
Process 9	Lv.	4.60	8.56	9.3	11.4	13.6	14.6	16.0
Free Held Torch	Rec.	7.14	7.49	8.0	11.2	14.8	17.4	19.8
	AV.	5.87	8.02	8.6	11.3	14.2	16.0	17.9
Process 10, hard	Lv.	3.19	5.00	4.4	7.1	8.5	10.8	11.3
Not rehardened	Rec.	6.69	4.37	4.7	8.9	10.9	13.6	14.1
Graham's	AV.	4.93	4.68	4.55	8.0	9.7	12.2	12.7
Process 10, hard	Lv.	3.74	5.42	5.8	7.9	11.5	12.2	17.0
Rehardened	Rec.	6.03	4.65	4.9	9.5	10.8	12.2	13.9
Graham's	AV.	4.88	5.03	5.3	8.7	11.2	12.2	15.4
Unhardened	Lv.	7.67	12.3	12.4	14.2	16.9	18.0	23.9
	Rec.	11.9	13.7	11.5	12.0	13.1	14.1	20.0
	AV.	9.79	13.0	12.0	13.1	15.0	16.1	22.0
Process 10, soft	Lv.	4.18	8.04	8.1	9.9	11.8	12.2	13.7
Graham's	Rec.	6.78	7.69	8.2	8.4	9.8	11.0	13.9
	AV.	5.48	7.86	8.15	9.15	10.8	11.6	13.8
Process 2, Mill E	Lv.	5.06	7.59	7.3	9.1	10.5	10.5	12.0
Gas heat	Rec.	8.43	7.39	7.2	7.8	8.5	9.7	11.6
Air quench	AV.	6.74	7.49	7.25	8.45	9.5	10.1	11.8
Process 3, Mill I	Lv.	5.45	7.75	7.7	8.6	10.2	10.2	11.3
Water quench	Rec.	4.04	5.35	7.0	9.6	12.2	14.6	14.8
Rolling heat	AV.	4.74	6.55	7.4	9.1	11.2	12.4	13.1
Process 1, Mill B	Lv.	3.87	7.21	10.1	16.0	18.0	18.1	19.0
Induction heat	Rec.	2.68	3.85	4.6	6.6	6.8	9.5	11.6
Water quench	AV.	3.27	5.53	7.4	11.3	12.4	13.8	15.3
Process 6, Mill D	Lv.	1.78	4.15	5.6	8.0	9.8	8.6	10.8
Brunorized	Rec.	1.39	2.21	4.9	7.4	8.8	10.4	12.6
Air quench	AV.	1.58	3.18	5.3	7.7	9.3	9.5	11.7

Batter measured at point ¼ in. from end of rail.

Process 9. Free held oxyacetylene torch. Water quench. Both rail ends of a joint are slowly heated to 1500 deg. F. with free held oxyacetylene torch, then quenched to 300 deg. F. with water from a sprinkling can with small holes. After quenching, the hardened area is tempered by reheating to 650 deg. F. and allowed to cool in air.

Process 10. Graham's automatic heating and water quenching machine. Space between rail ends is filled with refractory cement. Both rail ends are heated to 1500 deg. F. in about 2½ min. by means of a mechanically oscillated oxyacetylene burner containing 11 small flames. In the automatic quench 700 cc. of water flows through 30 small holes in 13 sec.

Field Tests for Batter of End-Hardened Rails

Batter measurements on the end-hardened test rails on the Chesapeake & Ohio Railway near Carey, Ohio, were taken each year. The last readings were made the first week of May 1945, after a total of 267,372,180 tons of traffic had passed over this track. The usual procedure was followed in measuring batter; that is, the rail profile was taken with the 48-in. batter gage, this was plotted to scale and a 24-in. straight-edge was laid on the plotted profile curve of each rail in the joint, touching the highest part of the curve near the end-hardened zone, and the batter was measured as the distance from the rail surface to the straight-edge at a point ¼ in. from the end of the rail.

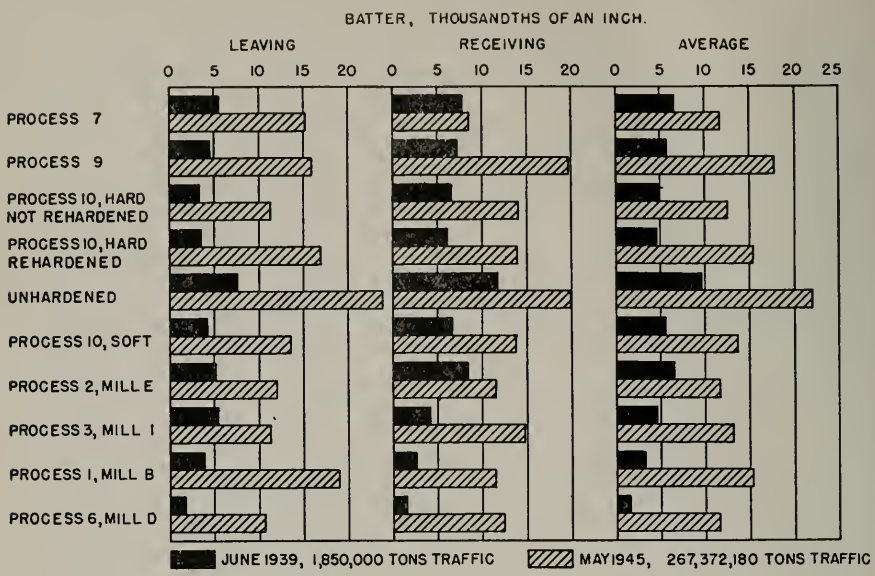

Fig. 1.—Comparative Batter, End Hardened Rails, Chesapeake & Ohio Railway, Carey, Ohio.

Table 1 gives a summary of the batter values obtained annually in this manner, and shows the average value for each process. Both leaving and receiving rails of all processes showed increases in batter for 1945 over 1944, the increases ranging from less than one thousandth to 5.9 thousandths of an inch. The unhardened rails, which have the greatest total batter also show the greatest increase (5.9 thousandths inch) over last year. The process 10, hard (not rehardened) rail ends which have the greatest hardness (Brinell 520) show the least increase over last year. Five of the processes show greater batter values for the receiving rails than for the leaving rails, while the remaining four processes and the unhardened group show greater batter values for the leaving rails.

Fig. 1 shows the comparison of batter values as of June 1939, when measurements were first taken with the 48-in. gage, and as of May 1945, after 267,372,180 tons of traffic. Weeping cracks in many rail ends continue to increase in size. At the time the batter measurements were taken, several rail ends had pieces cracked off an inch or more in length along the running surface of the rail head so these rails could not be included in this year's batter measurements. Four additional joints had been restored by welding at that time, and since then several more have been reported. As of June 1945, 24 additional joints over last year have been restored by welding, making 100 of these joints which have been deleted from the averages. These are:

60	Process 1, Mill B (Induction heat, water quench)
13	Process 3, Mill I (Water quench from rolling heat)
11	Process 10, hard, rehardened (Graham's water quench)
8	Process 10, hard, Not rehardened (Graham's water quench)
6	Process 9, (Free held torch, water quench)
2	Process 10, soft (Graham's water quench)
100	Total

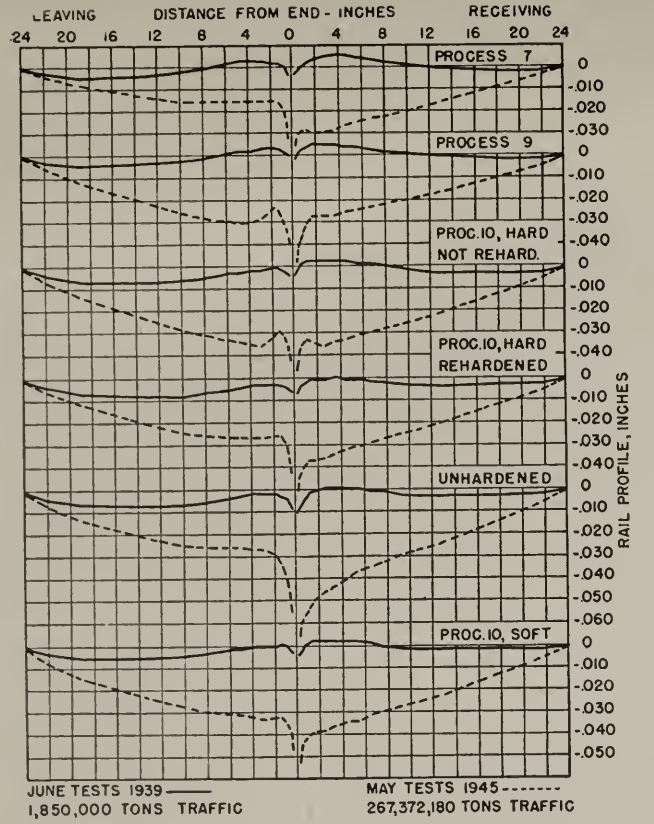

Fig. 2.—Average Joint Profiles, Field End-Hardened Rails.

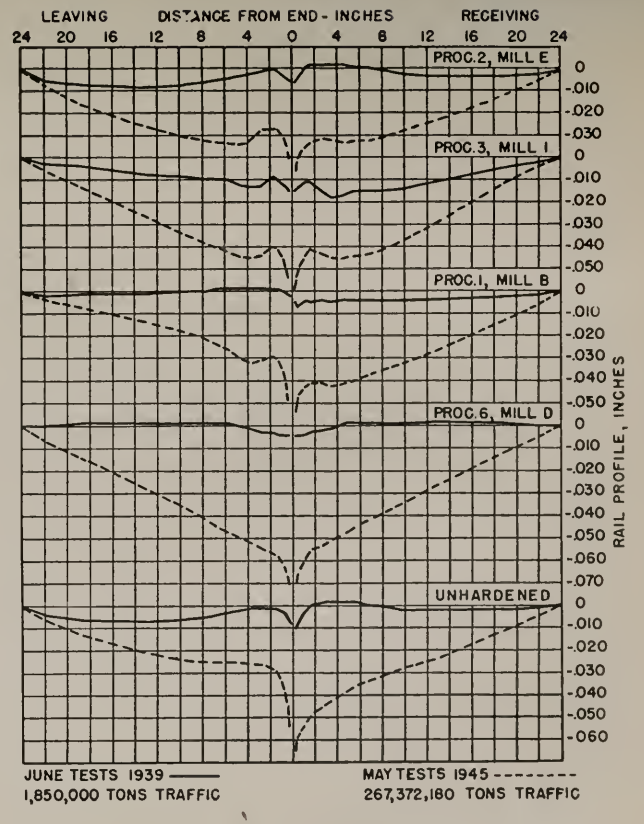

Fig. 3.—Average Joint Profiles, Mill End-Hardened Rails.

The average joint profiles for June 1939, and May 1945, are shown in Figs. 2 and 3. The droop of the joints has increased, the rail ends ranging from 35 to 71 thousandths of an inch low for the different processes with a few individual joints over 100 thousandths low at the rail ends. Some difference in elevation exists between leaving and receiving rail ends, with the receiving ends lower by four to eleven thousandths for all the processes except Process 6. The fact that many of the receiving rails are lower than the leaving rails, has in some instances caused the wheels to skip a small area at the end of the receiving rail with a consequent reduction of the end batter on the receiving rail. While this condition gives a low batter value for the receiving rail it does not necessarily mean that this is the best riding track when consideration is given to the difference in height of the leaving and receiving rail ends.

It is interesting to note that the three end-hardening processes which did not develop cracks of sufficient size to require welding now show average batter values only approximately one-half as great as the batter for the unhardened rails.

TABLE 2.—COMPARISON OF NUMBER OF CRACKED RAILS AND WELDED JOINTS IN CAREY TEST TRACK FOR THE YEARS 1944 AND 1945

Tons of Traffic to May 1945—267,372,180

Method of End Hardening	*Average Brinell Hardness*	*Total 1944*		*Total 1945*		*Increase 1944 to 1945*	
		Cracked Rails	*Welded Joints*	*Cracked Rails*	*Welded Joints*	*Cracked Rails*	*Welded Joints*
Oxweld Acetylene heated No quench	369	2	0	3	0	1	0
Free held torch Acetylene heated Water quench	426	34	4	38	6	4	2
Graham, hard-16 joints	520	12	7	13	8	1	1
Graham, rehard-84 joints Acetylene heated Water quench	366	36	9	42	11	6	2
Unhardened rails	287	3*	0	3*	0	0	0
Graham, soft Acetylene heated Water quench	364	18	2	19	2	1	0
Mill E Gas heated Air quench	361	2*	0	2*	0	0	0
Mill I Water quench from rolling heat	384	40	6	44	13	4	7
Mill B Induction heated Water quench	408	90	48	90	60	0	12
Mill D—Brunorized Air quench from normalizing temperature	374	7*	0	7*	0	0	0
Total		244	76	261	100	17	24

* These cracks are all at the gage corners and are head checks which have come out on the rail ends They should not be considered as defects in the hardening process.

Examination of Carey End-Hardened Rails for Weeping Cracks

The 900 test rails in the Chesapeake & Ohio track at Carey, Ohio, were last examined for weeping cracks in May 1945. The tonnage over the rails at that time was 267,372,180 tons. The number of cracked and welded rails found in 1945, compared with 1944, is given in Table 2. It will be noted that 17 additional cracked ends were found, and 24 more rails were built up by welding during the past year.

Conclusions

The following conclusions can be drawn from the study of this test track.

1. There is a decided reduction in end batter of end-hardened rails over those not end-hardened.
2. Rails quenched with water developed many weeping cracks while very few developed in air quenched or self-quenched rails.
3. The average Brinell hardness of the rails in the three air quenched groups which have not required welding up of rail ends was in the range 361 to 374.
4. Rail ends made too hard then rehardened to a lower hardness developed many weeping cracks.

End-Hardening Recommendations

Sufficient information has now been obtained from the many years of laboratory testing and field observations to warrant a preliminary draft of a recommended practice for the end-hardening of rails. These recommendations will necessarily be broad in scope and will be designed to serve for either mill or field practice.

Proposed Recommendations for End Hardening Rails

1. The area reheated for hardening should cover the full width of the rail head and extend longitudinally on the top surface between 1½ and 3½ in. from the end of the rail and to a depth of not less than ¼ in.
2. Heating for hardening should be completed in a time not exceeding five minutes.
3. Quenching should be performed by a process designed to avoid the formation of martensite. Water should not be employed as a quenching medium.
4. Rails hardened in accordance with instructions in Paragraph 1 shall show a Brinell hardness at a point ¼ in. to ½ in. from the end on a center line beneath the decarburized surface in accordance with the following:

Nominal Weight Per Yard	*Permissible Range in Brinell Hardness*
90 lb. to 120 lb.	331 to 401
121 lb. and over	341 to 415

5. Care should be taken to avoid abrupt changes in hardness in the hardened zone.

III Examination of Control Cooled and Brunorized Rails Which Failed in Service

During the past year, 25 control cooled rails were sent to the university laboratory for examination of the failures. Table 3 summarizes the causes of failure and Table 4 lists each rail separately.

It will be noted that porosity is the cause of the largest number of transverse fissures in the control cooled rails sent to this laboratory. However, porosity is still a very minor cause of rail failures considering that there are in service around 10 million control-

Table 3.—Summary of Failures of Control Cooled and Brunorized Rails

Transverse fissures from porosity	11
Compound fissures from porosity	1
Transverse fissures from shatter cracks	
Control cooled rails (loose lids on containers)	3
Brunorized rails (old process)	1
Detail fractures from shelly spots	3
Head and web separation	2
Fracture from base seam	1
Laminated rail from low side of curve	2
Wheel burned rail	1
Total	25

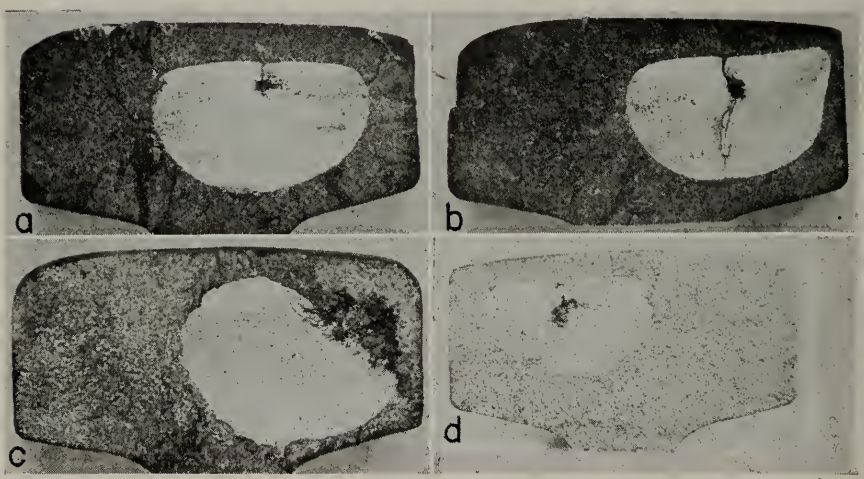

Fig. 4.—Typical Transverse Fissures From Porosity.

In some cases it is difficult to determine if the nucleus of a fissure is a shatter crack or a porous spot. If both faces of the fissure show a concave nucleus, it must have been a hole or porous spot.

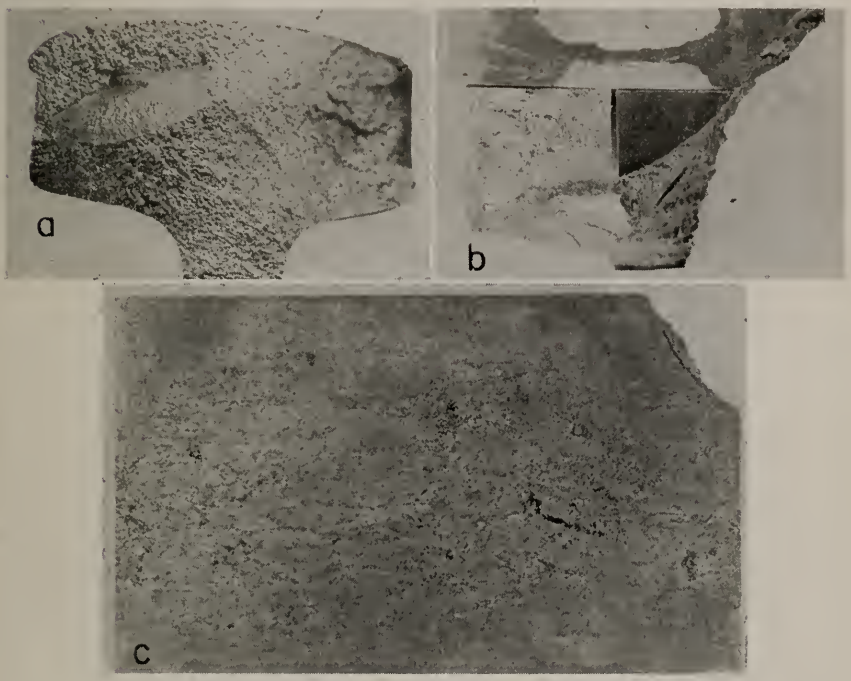

Fig. 5.—Compound Fissure From Porosity.

Lab. failed rail No. 399. Steelton, control cooled, 131-lb. rail. Heat No. CH86030–C–4, Rolled 2–1938. Supplied by L. T. Nuckols, chief engineer, Chesapeake & Ohio Railway.

View (a) shows the fracture with compound fissure.

View (b) shows a top view after removing the metal above the horizontal crack. Note the rough, porous nucleus.

View (c) shows an etched slice through the head which shows that the steel was porous throughout.

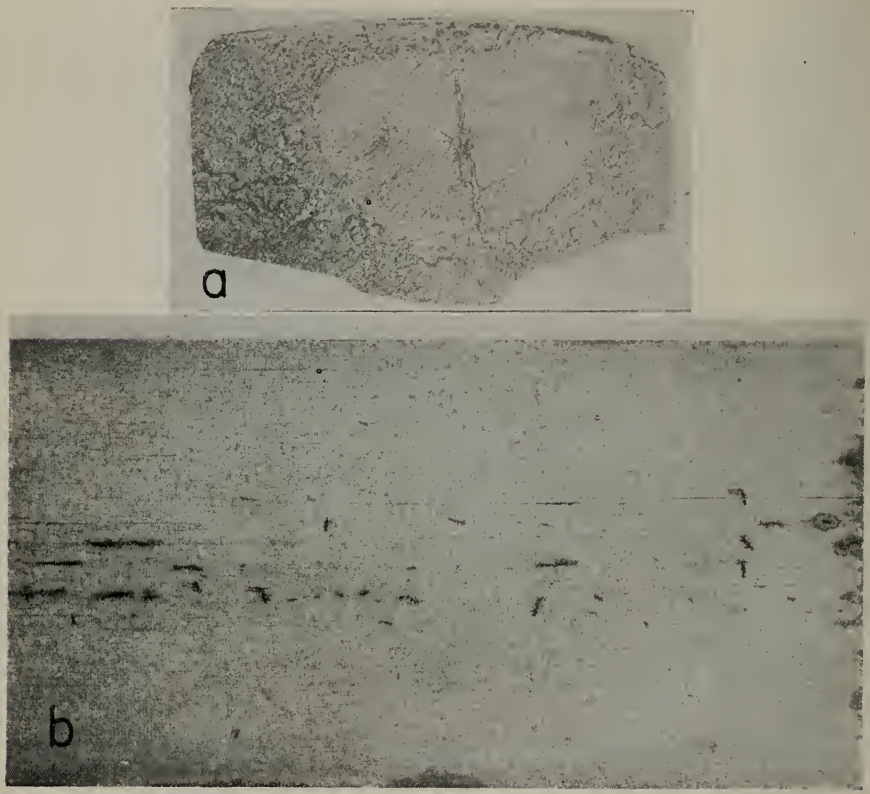

Fig. 6.—Transverse Fissure From Shatter Crack.

Lab. failed rail No. 400. Gary, control cooled, 112-lb. rail. Heat No. CH44485–B–15, Rolled 12–1936. Supplied by H. R. Clarke, chief engineer, Chicago, Burlington & Quincy Railroad.

View (a) shows a 25 percent transverse fissure with a small nucleus.

View (b) shows an etched slice from the rail head.

This was one of two more rails found which were rolled the first year of control cooling before the mill cooling containers had tight fitting lids. This condition was corrected the second year of control cooling.

TABLE 4.—LIST OF FAILED CONTROL COOLED RAILS EXAMINED AT TALBOT LABORATORY

From September 1, 1944, to September 1, 1945

D.F. = Detail Fracture
T.F. = Transverse Fissure
S.C. = Shatter Crack
C.F. = Compound Fissure
V.S.H. = Vertical Split Head

Source of Failed Rail	*Approximate Date of Failure*	*Lab. Failed Rail No.*	*Mill*	*Heat No. Rail Letter and Ingot*	*Date Rolled*	*Classification of Failure*
C & O	Aug. 11, 1944	388	Inland	14592–C–5	June 1936	D. F. from shelly spot
S. P.	Before Oct., 1944	389	Steelton	83175–G–10	1936	T. F. from porosity
U. P.	Aug. 13, 1944	390	Inland	33236–E–11	May 1939	T. F. from porosity
D. & H.	Before Oct. 1944	391	Steelton	C. H. 89190	April 1941	D. F. from shelly spot
S. P.	Sept. 23, 1944	392	Steelton	C. C. 81398–B–4	1936	T. F. from porosity
S. P.	Sept. 28, 1944	393	Steelton	C. C. 86019–B–16	1937	T. F. from porosity
D. T. & I.	Dec., 1944	396	Lackawana		Dec. 1936	Head and web separation 18° curve
N. Y. C.	Before Dec., 1944	397	Gary	B. N. 48206–D–6	Feb. 1937	Brunorized rail, Old process, T. F. from S. C.
C. & O.	Before Dec., 14, 1944	399	Steelton	C. H. 86030–C–4	Feb. 19, 1938	C. F. from porosity
C. B. & Q.	Before Dec. 1, 1944	400	Gary	C. H. 44485–B–15	Dec. 1936	T.F. from S.C. Improper control cooling
C. B. & Q.	Before Dec. 1, 1944	401	Gary	C. H. 44485–E–14	Dec. 1936	T.F. from S.C. Improper control cooling
S. P.	Before Nov. 22, 1944	403	Steelton	C. H. 88220–B–4	May 1936	T. F. from porosity
R. F. & P.	Feb., 1945	406	Steelton	85123–D–16	Feb. 1940	T. F. from porosity
I. C.	Feb., 1945	407	Gary	850263–E–21	May 1944	Fracture from base seam
N. & W.	Fall—1944	408	Steelton	88007–E–2	Dec. 1939	T. F. from porosity
N. & W.	Fall—1944	409	Steelton	83585–E–7	Sept. 1940	T. F. from porosity
C. & O.	June—1945	413	Inland	17780–G–19	March 1937	Head and Web separation
P. & L. E.	July—1945	414	Edgar Thomson	205156–C–3	April 1940	D. F. from shelly spot
C. & O.	June—1945	417	Inland	23275–D–20	Aug. 1936	T. F. from porosity
N. Y., N. H. & H.	July—1945	418	Steelton	82091–B–7	March 1940	T. F. from porosity

TABLE 4.—Continued

Source of Failed Rail	Approximate Date of Failure	Lab. Failed Rail No.	Mill	Heat No. Rail Letter and Ingot	Date Rolled	Classification of Failure
N. Y., N. H. & H....	July—1945	419	Edgar Thomson	211300–E–9	July 1937	T.F. from silicate inclusion (one cavity)
N. & W.....	July—1945	421	Edgar Thomson	14E286–B–3	June 1944	Laminated rail from low side of curve
N. & W.....	July—1945	422	Edgar Thomson	14E286–B–7	June 1944	Laminated rail from low side of curve
N. & W.....	July—1945	423	Edgar Thomson			Wheel burned rail
C. B. & Q.....	Aug.—1945	424	Gary	56308	1936	T.F. from S.C. Improper control cooling

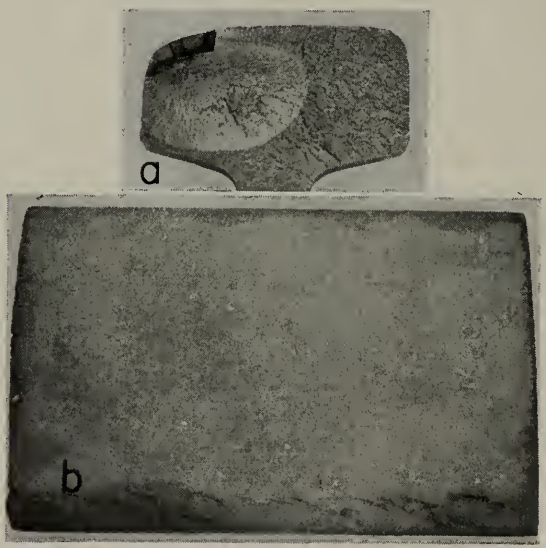

Fig. 7.—Detail Fracture From Shelly Spot.

Lab. failed rail No. 402. Gary, control cooled, 112-lb. rail. Heat No. 42542–2–A, Rolled 12–1936. Supplied by E. C. Vandenburgh, engineer of maintenance, Chicago & North Western Railway.

View (a) shows a 50 percent detail fracture which spread from a shelling crack about 3/8 in. below the tread.

View (b) shows the gage corner of this rail after etching in acid to enlarge head checks on the gage corner. Service which produces such head checks often produces shelling.

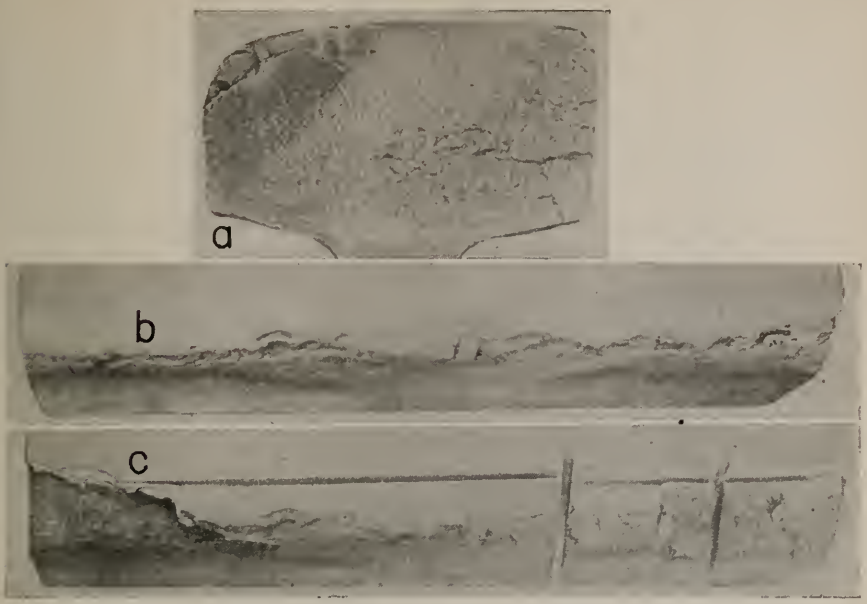

Fig. 8.—Detail Fracture From Shelly Spot.

Lab. failed rail No. 391. Steelton, control cooled, 112-lb. rail. Heat No. CH89190, Rolled 4–1941. Supplied by P. O. Ferris, chief engineer, Delaware & Hudson Railroad Corporation.

View (a) shows about an 80 percent detail fracture starting near the gage corner.

View (b) shows the gage corner of the rail after etching in acid.

View (c) shows the same area after opening up the shelling cracks. These cracks extended in from the gage corner 3/8 in. to 1/2 in.

cooled rails. Fig. 4 shows photographs of four of these failures. Fig. 5 shows the compound fissure from porosity. The mill metallurgists are investigating the cause of porosity found in a few rails, but so far have not reached a definite conclusion as to its cause.

One of the three transverse fissures from shatter cracks is shown in Fig. 6. These were the result of improper control cooling of rails rolled in 1936 before the mill had tight fitting and insulated lids on their cooling cars. Fig. 7 shows a detail fracture from a shelly spot in a rail which also had head cracks at the gage corner. Fig. 8 shows a detail fracture in a rail which has developed severe shelling cracks.

IV Control Cooling of Three Percent Chromium and Intermediate Manganese Rails

The staff members of this investigation were invited to observe an experiment on the control cooling of three percent chromium rails at the Gary rail mill, November 29 and 30, 1944. One ingot was treated with 80 cu. ft. of hydrogen gas to induce sensitivity to shatter cracking in rails from this ingot. All rails from this ingot not used in the experiment were of course scrapped. Specimens from the drop test rails of the second, middle and last ingot, not treated with hydrogen, were air cooled, but did not contain shatter cracks. Only a few longitudinal shatter cracks were found in the rails from the ingot treated with hydrogen as shown in the following Table 5.

Table 5.—Etch Test of Hydrogen-Treated Specimens Cooled in Various Ways

Specimen Number	*Method of Cooling*	*No. Longitudinal Shatter Cracks in 6-in. Slice*
1	Air cooled to room temperature	1
2	Air cooled to 1000 deg. F.—Held 1½ hrs. then air cooled	2
3	Air cooled to 1000 deg. F.—Held 3 hrs. then air cooled	None
4	Air cooled to 600 deg. F.—Held 1½ hrs. then air cooled	2
5	Air cooled to 600 deg. F.—Held 3 hrs. then air cooled	None
6	Air cooled to 200 deg. F. Reheated to 1000 deg. F. control cooled	5
7	Air cooled to 100 deg. F. Reheated to 1000 deg. F. control cooled	3
8	Air cooled to room temperature—held 2 hrs. then reheated to 1000 deg. F. and control cooled	2
9	Air cooled to room temperature—held 24 hrs. before sawing	1

It may seem strange that the greatest number of shatter cracks were found in rails cooled to 200 deg. F. and 100 deg. F., then reheated to 1000 deg. F. One possible explanation is that enough hydrogen gas had come out of solution, during the rather long time required to cool to these temperatures, inside the steel in some small voids so that the reheating to 1000 deg. F. expanded this gas enough to cause an internal pressure which could rupture the surrounding metal. Several 6-ft. lengths of these chromium rails were supplied the rails investigation for future laboratory tests.

From the results of these tests it appears that this chromium steel is not very sensitive to the development of shatter cracks. Ordinary rail steel treated with 80 cu. ft. of hydrogen gas would have contained a large number of shatter cracks when cooled in air. The additional strength of the chromium steel together with its low carbon content (0.35 percent) may be the reason it is not sensitive to cracking.

In February 1945, the Ensley mill rolled two heats of control cooled intermediate manganese rails and the staff members were invited to observe the effect of the control cooling on this type of rail. Several specimens were taken from the fastest cooling rails in the cooling boxes and all were found to be free of shatter cracks while some specimens cut at the hot saws and cooled in air did develop a few longitudinal shatter cracks. Two 6-ft. lengths of these intermediate manganese rails were supplied the rails investigation for laboratory tests.

Report of Committee 5—Track

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E. W. Backes
A. L. Bartlett
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Blair Blowers
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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Revision of various portions, submitted for adoption..... page 482

2. Fastenings for continuous welded rail, collaborating with Committee 4—Rail.

   No report.

3. Plans and specifications for track tools including their repair and reclamation, with recommended minimum limits for reclaimed tools, collaborating with Committees 1, 22, and with Purchases and Stores Division, AAR.

   Progress report, including recommended changes in plans and specifications in the Manual ..... page 484

4. Plans for switches, frogs, crossings, spring and slip switches, collaborating with Signal Section, AAR.

   Preliminary report of progress in stress measurements published in Bulletin 453, June–July 1945..... page 1

   Progress report, including recommended revisions of trackwork plans..... page 489

5. Prevention of damage due to brine drippings on track and structures, collaborating with Mechanical Division, AAR.

   No report.

6. Design of and stresses in tie plates, collaborating with Committees 3 and 4.

Preliminary report of progress in stress measurements published in Bulletin 453, June–July 1945..... page 1

Progress report, presented as information..... page 491

7. Welding of manganese castings in special trackwork, collaborating with Committee 27.

Progress report, presented as information..... page 515

8. Effect of lubrication in preventing frozen rail joints.

Progress report, presented as information..... page 523

9. Recommendations on number and placing of anti-creepers for various conditions.

Progress report, presented as information..... page 527

10. Investigate reactance value of spring washers, collaborating with Committee 4.

No report.

11. Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3A —General Reclamation of the Purchases and Stores Division, AAR.

No report.

THE COMMITTEE ON TRACK,
I. H. SCHRAM, *Chairman.*

Report on Assignment 1

Revision of Manual

C. R. Strattman (chairman, subcommittee), L. L. Adams, C. A. Anderson, W. G. Arn, T. H. Beebe, Blair Blowers, C. W. Breed, H. R. Clarke, M. H. Dick, J. A. Ellis, J. E. Fanning, R. A. Gravelle, A. B. Hillman, C. T. Jackson, J. deN. Macomb, L. H. Roden, R. R. Smith, J. G. Wishart, M. J. Zeeman.

Your committee offers the following recommendations for revisions of the Manual:

Pages E–5–10 and E–5–11

Withdraw the emergency tie plate plans E and F.

Page 5–18

Withdraw the matter on Design of Track Fastenings.

Page 5–49

In Specifications for Track Tools, insert references to tools as follows:

27. Rail Tongs for Use With Crane—Plan No. 23

No special test required.

28. Track Gage With Wood Rod—Plan No. 20-A

No special test required.

Page 54.1

Insert the following in the table of track tools:

20-A	Track Gage With Wood Rod		
23	Rail Tongs for Use With Crane	O.H. or Alloy	†

Your committee offers the following recommendations for revisions of or additions to the Glossary in the Manual:

On page 20, under "Gage (of Track)" add: "See also Plan Basic 791, Trackwork Plans."

On page 19, under "Flangeway" add: "See also Plan Basic 791, Trackwork Plans."

Revise the definition of "Curved Lead" on page 12 to conform with that in the Glossary of the Trackwork Plans to read as follows:

CURVED LEAD.—The distance between the actual point of the switch and the half-inch point of the frog, measured on the outside gage line of the tangent. *5*

For the same reason, change the definitions of Lead Curve and Level as follows:

LEAD CURVE.—The curve in the turnout interposed between the switch and the frog. *5*

LEVEL.—The condition of the track in which the elevation of the two rails transversely is the same. *5*

Insert in the Glossary of the Manual the following terms which now appear only in the Glossary of the Trackwork Plans:

COMPROMISE JOINT (Rail).—A joint for uniting the abutting ends of contiguous rails of different sections, or of rails of the same section but of different joint drillings. *5*

COMPROMISE RAIL.—A relatively short rail the two ends of which are of different section, corresponding with the sections of the rails to which they are to be joined; it provides the transition from one section to a different rail section. *5*

SELF GUARDED FROG (Flange Frog).—A frog provided with guides or flanges, above its running surface, which contact the tread rims of wheels for the purpose of safely guiding their flanges past the point of the frog. *5*

CROSSOVER.—Two turnouts with the track between the frogs arranged to form a continuous passage between two nearby and generally parallel tracks. *5*

Report on Assignment 3

Plans and Specifications for Track Tools Including Their Repair and Reclamation, with Recommended Minimum Limits for Reclaimed Tools

Collaborating with Committees 1, 22 and with Purchases and Stores Division, AAR

W. E. Cornell (chairman, subcommittee), E. W. Caruthers, Blair Blowers, A. E. Botts, E. J. Brown, E. D. Cowlin, L. W. Deslauriers, J. A. Ellis, R. A. Gravelle, C. E. R. Haight, H. H. Harman, E. E. Martin, J. B. Myers, C. J. Rist, L. H. Roden, M. K. Ruppert, R. R. Smith, J. G. Wishart.

Your committee submits, for adoption and publication in the Manual, combined specifications for ash and hickory handles. It is of the opinion that there is a definite need for ash handle specifications and that the combining of such specifications with the present hickory handle specifications has been accomplished with full clarity and with considerable saving in Manual space.

SPECIFICATIONS FOR ASH AND HICKORY HANDLES FOR TRACK TOOLS

1946

1. Material

Before manufacturing tool handles, the manufacturer shall ascertain which of the following kinds of ash or hickory will be accepted. Other woods will not be accepted unless specifically ordered.

Ash for fork, hoe, rake, scoop, shovel, and scythe handles.

Black ash *(Fraxinus nigra)*
Green ash *(Fraxinus pennsylvanica lanceolata)*
Oregon ash *(Fraxinus oregona)*
White ash *(Fraxinus americana)*

Hickory for adze, axe, canthook, chisel, hammer, hatchet, jack, maul, pick, punch and sledge handles.

Bitternut hickory *(Hicoria cordiformis)*
Mockernut hickory *(Hicoria alba)*
Nutmeg hickory *(Hicora myristicaeformis)*
Pignut hickory *(Hicoria glabra)*
Shagbark hickory *(Hicoria ovata)*
Shellbark hickory—Bigleaf *(Hicoria laciniosa)*
Water hickory *(Hicoria acquatica)*

2. Physical Requirements

Except as hereinafter provided, all tool handles shall be seasoned to a moisture content not exceeding 12 percent, and shall be free of injurious characteristics that may impair their serviceability, such as decay, cross-grain, abrupt grain-dip, holes, large knots, splits, heavy stain, warp, and lightweight wood.

Any tool handle may be either all heartwood, all sapwood, or a mixture of both.

3. Design

Tool handles shall conform to the design and dimensions shown on AREA plans which form a part of these specifications, with an allowable variation of ¼ in. over or under in length and 1/16 in. over or under in all other dimensions.

4. Manufacture

Tool handles shall be cut square at the ends, uniform in size and shape for each type, smoothly finished, and waxed. Lacquered, painted, or stained handles are not acceptable.

The manufacturer shall legibly impress into each accepted handle, at a location and in a manner that will not weaken the handle and at a location designated by the purchaser, whatever grade, maker, or ownership symbol may be required by the purchaser.

5. Inspection

Handles will be inspected at points of manufacture, shipment, or destination, in suitable and convenient places satisfactory to the purchaser.

Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while work on the contract of the purchaser is being performed, and shall have all reasonable facilities (including adequate light) afforded them, free of cost, to satisfy them that the handles being supplied are in accordance with these specifications.

Inspectors will make a reasonably close examination of each handle and acceptance or rejection will be based on visual inspection and the judgment of the inspector. He will not determine the exact weight and density of each handle, but in case of question, one or both of these characteristics may be accurately measured for conformance with the requirements for each grade. Exactness of size and shape will be checked by accurate measurements of handles taken at random.

Each handle will be judged independently, without regard for the decisions on others in the same lot.

The inspector shall have his identifying designation legibly branded into the grasp end of each accepted tool handle.

6. Definitions of Blemishes and Defects

cross grain.—Deviation of the fiber out of parallel with the axis of the handle in excess of 1 in 12 for ash and 1 in 20 for hickory.

abrupt grain dip.—Deviation of the fiber out of parallel with the axis of the handle in excess of ⅛ the diameter of the handle where the grain dip occurs.

slight grain dip.—Deviation of the fiber out of parallel with the axis of the handle not in excess of ⅛ the diameter of the handle where the grain dip occurs.

hole.—Holes (including bird pecks) may extend partially or entirely through the piece and be from any cause.

pin knot.—Average diameter not more than 1/16 in.

small knot.—Average diameter more than 1/16 in., but not more than ⅛ in.

medium knot.—Average diameter more than ⅛ in., but not more than ¼ in.

split.—Lengthwise separation of the wood extending from one surface through the piece to the opposite surface or an adjoining surface.

light stain.—Slight difference in color which does not materially change the appearance of the handle.

medium stain.—Pronounced difference in color which does not obscure the grain of the wood.

small streak.—Threadlike discoloration extending not more than ⅓ the length of the handle.

medium streak.—Discoloration extending more than ⅓ the length of the handle, but not over $\frac{1}{32}$ in. wide.

large streak.—Discoloration over $\frac{1}{32}$ in. wide.

7. Delivery

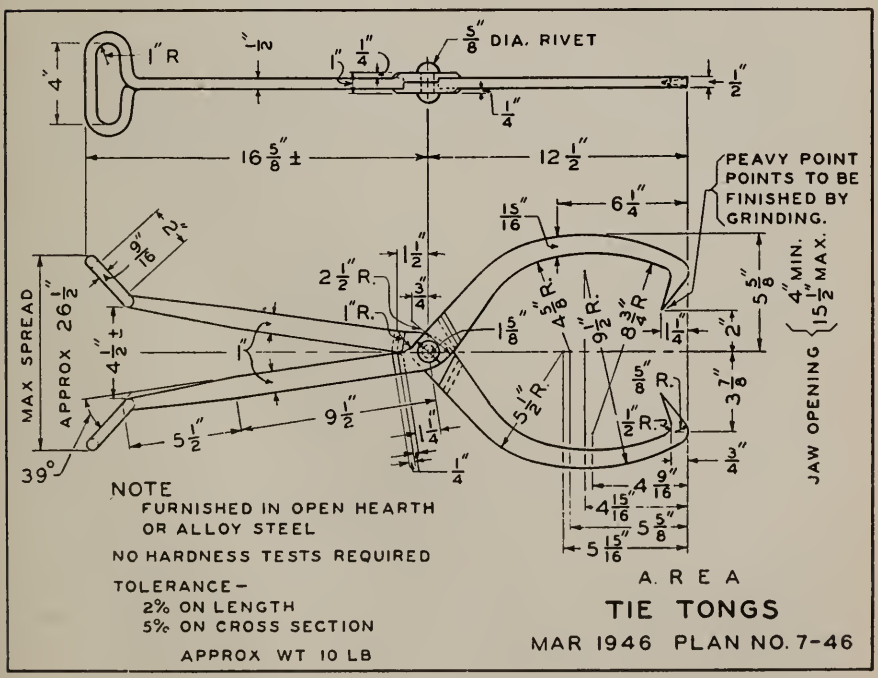
Accepted handles shall be shipped in accordance with the instructions in the order covering them, securely packed in containers marked with the name, type, grade, and quantity of the material therein and with the name of the shipper and the number of the purchaser's contract or order.

8. Grade Classification

Grade Symbol	*Color*	*Maximum Number of Annual Rings per Inch of Radius*	*Minimum Weight per Cu. Ft. Lb.*	*Maximum Slope of Grain*	*Admissible Blemishes and Defects*
AA	White, red or brown, or brown, red, and white; but dark brown or dark red only within 10 in. from tool end.	15	43	1 in 12	1 slight grain dip; tight pin knots and small streaks at least 12 in. apart; light stain.
AB	White, red, or brown, or brown, red, and white; but dark brown or dark red only within 10 in. from each end.	18	36	1 in 12	1 small tight knob at each end; 2 slight grain dips and 2 tight pin knots at least 6 in. apart; medium stain; 2 small streaks.
HA	Red or white or red and white.	17	55	1 in 50	Light stain; medium streaks.
HB–1	Red or white or red and white.	22	46	1 in 50	Medium stain; large streak; bird pecks or tight knots not more than ¼ in. in average diameter, in the eye end or first third of the grasp end.
HB–2	Red or white or red and white.	27	46	1 in 20	Medium stain; slight grain dip; large streak; bird pecks or tight knots, the sum of whose average diameters does not exceed ¼ in., in the eye end or the first third of the grasp end.

9. Use Classification.

Handle	Handle Grade Symbol	Minimum Weight per Dozen Handles Lb.	Number of Tool Plan
Adze—34 in.	HA	15	12
Axe—36 in.	HA	17	----
Canthook	HB–1	----	----
Chisel (Track) 22 in.	HB–2	7	17
Fork (Ballast)	AA	----	22
Hammer	HA	----	----
Hatchet	HA	----	----
Hoe	AB	----	----
Jack	HB–1	----	----
Maul (Spike) 36 in.	HA	15	3
Pick—36 in.	HA	21	1 & 2
Punch (Round track) 22 in.	HB–2	7	19
Punch (Tie-plug) 22 in.	HB–2	7	18
Rake	AB	----	----
Scoop	AA	----	26
Scythe (Snath) 59 in.	AA	----	29
Shovel (Track)	AA	----	21
Sledge—36 in.	HA	14	13



The committee also recommends the following changes in the material now in the Manual.

Tie Tongs—Plan No. 7–41

That Plan No. 7–46 be adopted for publication in the Manual superseding Plan No. 7–41.

Rail Fork—Plan No. 10

That this plan be removed from the Manual.

Definition of Grades—ash handles and specifications for track shovels shown on page 5–53 of the Manual.

That all the material on this page be deleted from the Manual and that the specifications for track shovels as presented below be inserted on page 5–49.

25. Track Shovel—Plan 21

1. Scope and Design

This specification covers both the welded or riveted type and the solid shank type with either wood, malleable iron or combination wood-metal handle tops. Dimensions shall conform to plans, which are made a part of this specification. A variation of ½ in. more or less from the dimension shown on the plan for the length of the strap or shank and handle will be allowed. A variation of ¼ in. more or less from the dimensions shown on the plan for the width or length of the blade will be allowed, but the total variation in the overall length of shovels shall not exceed ½ in., more or less of the dimensions shown on plan.

2. Materials

Blades shall be of open-hearth, crucible, electric furnace or alloy steel, with a Rockwell hardness for carbon steel of 45 to 50.

Carbon steel blades shall have a thickness of not less than No. 13 gage and alloy blades shall be of not less than No. 14 gage U. S. standard, the gage to be measured at the point where the hardness is taken. For welded or riveted types, the straps shall be welded or riveted to the blade.

3. Handles and Tops

Handles shall be made of ash and shall conform to Grade AA as set forth in the general Specifications for Handles for Track Tools. The tops of handles shall be of the design specified and shall conform to plans that are made a part of this specification.

4. Tests

One shovel from each lot of 10 dozen or less shall be selected and metal straps (curved to fit the contour of the handle) shall be clamped to the upper and lower parts of the handle, after which the shovel shall be placed in a prying position, supported at the end of the blade by clamps and shall be capable of sustaining a load of 200 lb. suspended from the end for a period of 2 min. without showing any permanent set, fracture or distortion.

Alloy steel shovels which have been given a heat treatment to insure uniformity in hardness shall be subjected to a shock test to insure against brittleness. The test shall be made by forcibly striking the blade of the shovel with a hand hammer at several places when placed on an anvil.

Ballast Forks—Specifications shown on page 5–54 of the Manual

That these specifications be revised to read as follows and inserted on page 5–49.

26. Ballast Fork—Plan No. 22

1. Scope and Design

This specification covers either wood, malleable iron or combination wood-metal handle tops. The dimensions shall conform to the plans, which are made a part of this specification. The total variation in the overall length of forks shall not exceed ½ in., more or less of the dimensions shown on plan.

2. Material

Forks shall be made of high grade open-hearth steel.
Tines of forks shall show Rockwell hardness of 35–45.
Straps shall be 0.04 U. S. standard gage steel.

3. Handles

Handles shall be made of ash and shall conform to Grade AA and be in accordance with the general Specifications for Handles for Track Tools.

Report on Assignment 4

Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section, AAR

E. W. Caruthers (chairman, subcommittee), L. L. Adams, J. C. Aker, C. A. Anderson, E. W. Backes, T. H. Beebe, F. J. Bishop, C. W. Breed, B. E. Crumpler, H. Q. Day, L. W. Deslauriers, J. A. Ellis, J. E. Fanning, J. W. Fulmer, R. A. Gravelle, N. M. Hench, A. B. Hillman, A. F. Huber, W. G. Hulbert, C. T. Jackson, L. I. Martin, F. H. Masters, R. E. Miller, J. B. Myers, G. A. Peabody, O. C. Rehfuss, C. J. Rist, L. H. Roden, G. J. Slibeck, C. R. Strattman, H. N. West, R. P. Winton, J. G. Wishart, M. J. Zeeman.

Your committee submits as information a report of progress on this assignment, together with several revisions of the Portfolio of Trackwork Plans.

Following favorable reports from the service records of railbound manganese steel turnout frogs made in accordance with tentative Plan 623–44–T, the committee is preparing a series of plans covering frogs of this type of the various numbers now in general use. The Standardization Committee of the Manganese Track Society is assisting in the preparation of these plans.

A progress report on Stress Measurements on Various Designs of Solid Manganese Crossing Frogs appeared in Bulletin 453.* Since the publication of this report, the Morden–Ramapo casting has been replaced by the Bethlethem design casting.

The batter on the Morden–Ramapo casting on both the Santa Fe receiving surface and B. & O. receiving surface was 0.18 in. (approximately $\frac{3}{16}$ in.), measured ¾ in. from the flangeway line.

Revision of Manual

Your committee recommends revisions in plans appearing in the Portfolio of Trackwork Plans, as follows:

* See page 1, this volume.

Plan 710–41 Bolted Rail Crossings, Angles 14° 15′ to 8° 10′ inclusive.
Revise to 710–45 and change Note 4 (a) to read as follows: For application of AREA crossing designs and recommended practice, see Plan Basic No. 700, and for limitations for the use of crossings with rigid center frogs, see Plan Basic No. 820.

Plan 768–41 Manganese Steel Insert Crossings, Angles 14° 15′ to 8° 10′ inclusive.
Revise to 768–45 and change Note 4 (a) to read as follows: For application of AREA crossing designs and recommended practice, see Plan Basic No. 700, and for limitations for the use of crossings with rigid center frogs, see Plan Basic No. 820.

Plan 775–41 Crossings with Solid Manganese Steel Frogs and Interior Rolled Closure Rails,Angles 14° 15′ to 8° 10′ inclusive—Single Rail Construction.
Revise to 775–45 and change Note 4 (a) to read as follows: For application of AREA crossing designs and recommended practice, see Plan Basic No. 700, and for limitations for the use of crossings with rigid center frogs, see Plan Basic No. 820.

Plan 820–35 Graph Showing Limitations for the Use of Crossings with Rigid Center Frogs, Angles up to 15° 30′ inclusive.
Revise to 820–45 and change Note referring to dotted graph line to read: Dotted graph line applies only for installations in yards and terminals.

The committee recommends the withdrawal of the Emergency Provisions adopted March 19, 1942, covering Trackwork Plans, which provided that:

1. The use of the following plans be suspended for the duration of the war:

Plan 220–42 Manganese Steel Points for Split Switches.

503–40 Guard Rails, Tee Rail Design, with Planed Flares and Canted Plates.

773–40 Solid Manganese Steel Crossings, Angles 40°–25° inclusive.

774–41 Crossings with Solid Manganese Steel Frogs, Angles below 25° and above 14° 15′.

775–41 Crossings with Solid Manganese Steel Frogs, Angles 14° 15′ to 8° 10′, inclusive.

983–35 Solid Manganese Steel Frogs for 7″ and 9″ Girder Rails.

2. The portion of Plan 821–42 showing Rail Bound and Solid Manganese Steel Knuckle Rails be suspended for the duration of the War.

3. The title of Plan 772–40 be revised to read: "Solid Manganese Steel Crossings, Angles below 60° to 45°" for the duration of the War.

Report on Assignment 6

Design of and Stresses in Tie Plates

Collaborating with Committees 3 and 4

J. de N. Macomb (chairman, subcommittee), L. L. Adams, W. G. Arn, E. W. Backes, Blair Blowers, A. E. Botts, W. S. Boyce, E. W. Caruthers, H. R. Clarke, O. U. Cook, J. E. Fanning, H. F. Fifield, B. F. Handloser, N. M. Hench, W. G. Hulbert, C. T. Jackson, G. M. Magee, A. E. Perlman, J. A. Reed, J. G. Wishart.

This progress report, submitted as information, covers stress measurements in seven designs of tie plates for 131-lb. RE rail on the Southern Railway System (C. N. O. & T. P. Ry.) near Chattanooga, Tenn.

Foreword

In last year's report, Proceedings. Vol. 46, 1945, page 593, a description was given of a test installation with various designs of tie plates for 112-lb. rail on the Illinois Central System near Dyersburg, Tenn., and for 131-lb. RE rail on the Southern Railway System near Chattanooga, Tenn. The purpose of both of these installations was to obtain data on stresses developed in the tie plates, localized stresses in the rail base and in the lower rail fillets over the tie plate bearing surface, and the effect on mechanical wear of ties and maintenance of gage of the various designs of plates. As a part of the work of the Engineering Division research staff during the summer of 1945, extensive stress measurements were made in the 131-lb. tie plate test on the Southern Railway near Chattanooga, and these tests will be described in this report.

Test Location

In selecting a location for the tie plate tests a number of factors were considered. It was desirable to have a heavy traffic density so the result of mechanical wear of ties would be accelerated. Fairly sharp curvature as well as tangent track was needed so the performance of tie plates could be observed under both of these conditions which have to be provided for in the design of tie plates. The location selected for the test on the 131-lb. tie plates was on Mile 326 of the single-track main line of the C.N.O. & T.P., approximately 12 miles north of Chattanooga. At this location there was a 6-deg. curve and tangent track suited to the test requirements.

The test tie plates were installed at this location in November 1944. At the time the installation was made the track was relaid with all new material, including 131-lb. rail, 6-hole joint bars, and the track was resurfaced on coarse stone ballast. A sufficient number of new treated ties were installed out of face on both tangent and curved track locations so that all of the test tie plates would be placed on new ties. The track was found to be in excellent condition at the time the stress measurements were made in August and September 1945. The photographs in Figs. 1 and 2 show the two test stretches of track.

Operating Conditions

The track was on a level grade for approximately one mile south of the test curve and for over two miles to the north. The 6-deg. curve had a 6-in. superelevation and the maximum authorized speed for all trains was 45 mph for both the curve and tangent test sections, the latter being immediately south of the curve.

Passenger trains were hauled by Pacific (4–6–2) and Mountain (4–8–2) types of locomotives. The driving axle load of the former was 60,000 lb. and of the latter class

Fig. 1.—View of North Portion of the Test Curve.

Fig. 2.—Tangent Track Test Section (Beyond Rail Oiler).

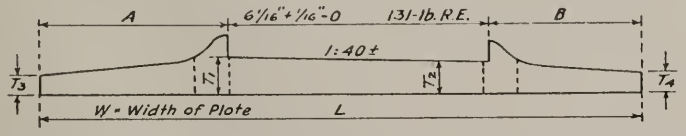
56,000 lb. The longest engine wheel base was 40 ft. Freight trains were hauled principally by several classes of Mikado (2–8–2) type locomotives with a maximum driving axle load of 60,700 lb. and a wheel base of 36 ft. 11 in. A small number of the freight trains were hauled by 3-unit diesel-electric locomotives with axle loads ranging from 52,000 to 60,000 lb.

Generally, the passenger train speeds were close to or slightly above the authorized speed of 45 mph., while the freight trains operated near the equilibrium speed of the curve which was 39 mph.

Neither the class of power used over this track nor the operating speeds may be expected to develop as severe conditions of stress in tie plates and rail base as would be obtained with modern, heavy locomotives of the 2–10–4 or 4–8–4 types operating at slow speeds around a 6-deg. curve with this amount of superelevation.

Tie Plate Designs and Arrangements of Test Panels

The different designs used in this test were selected for the purpose of developing information regarding the effect of tie plate thickness, length, amount of eccentricity, and type of rail seat. Figs. 3 to 10, inclusive, are detailed drawings of each of the 8 different designs of tie plates used in the test. In Table 1, the principal dimensions and other physical properties of the various tie plate designs have been summarized for more convenient comparison. Three of the tie plates, designs 831–X, 831–Y and 831–Z, are similar in all respects except for differences in thickness, varying from a minimum of $\frac{3}{4}$ in. under the outer shoulder to a maximum of $\frac{31}{32}$ in. Design 420 is comparable to design 831–Y except that design 420 is $\frac{1}{4}$ in. wider and has a flat rail seat as compared with a rolled circular crown rail seat. Design No. 5, 405 and 831 were included to show the effects of varying lengths of plates as well as the amount of eccentricity. Plan No. 405–A was installed on the curved track alone to determine the benefit of three transverse ribs on the bottom of the plate in holding the rail to gage. For all other designs the bottom of the plate was flat. All designs of plates provided a rail seat having a cant of approximately 1:40 and also had double shoulders. The arrangement of the 22 tie plate test panels is shown in Fig. 11.



Tie Plate Designation	Size W × L	A	B	Eccentricity	T_1	T_2	T_3	T_4	Rail Seat	Ratio $T_1 \div A$	Net Area of Plate Sq. in.	Estimated Net Weight - lb.
131 - lb. R. E. Rail												
831	7 1/4" × 14 3/4"	4 3/16"	3 7/8"	1/2"	31/32"	13/16"	3/8"	3/8"	Rolled Crown	.201	106.7	22.8
831-Z	7 1/2" × 14"	4 3/8"	3 9/16"	3/8"	31/32"	13/16"	27/64"	13/32"	Rolled Crown	.221	101.0	22.2
831-Y	7 1/2" × 14"	4 3/8"	3 9/16"	3/8"	7/8"	23/32"	21/64"	6/16"	Rolled Crown	.200	101.0	19.5
831-X	7 1/2" × 14"	4 3/8"	3 9/16"	3/8"	3/4"	19/32"	13/64"	3/16"	Rolled Crown	.171	101.0	15.9
420	7 3/4" × 14"	4 3/8"	3 9/16"	3/8"	7/8"	23/32"	7/16"	7/16"	Flat	.200	103.5	21.3
Plan No. 5	7 3/4" × 13"	3 3/4"	3 3/16"	1/4"	27/32"	11/16"	9/16"	9/16"	Rolled Crown	.225	97.3	19.3
405	8" × 12"	3 3/8"	2 9/16"	3/8"	3/4"	19/32"	5/16"	5/16"	Rolled Crown	.222	93.9	16.0
405-A	8" × 12"	3 3/8"	2 9/16"	3/8"	3/4"	19/32"	5/16"	5/16"	Rolled Crown	.222	93.9	16.3

TABLE 1

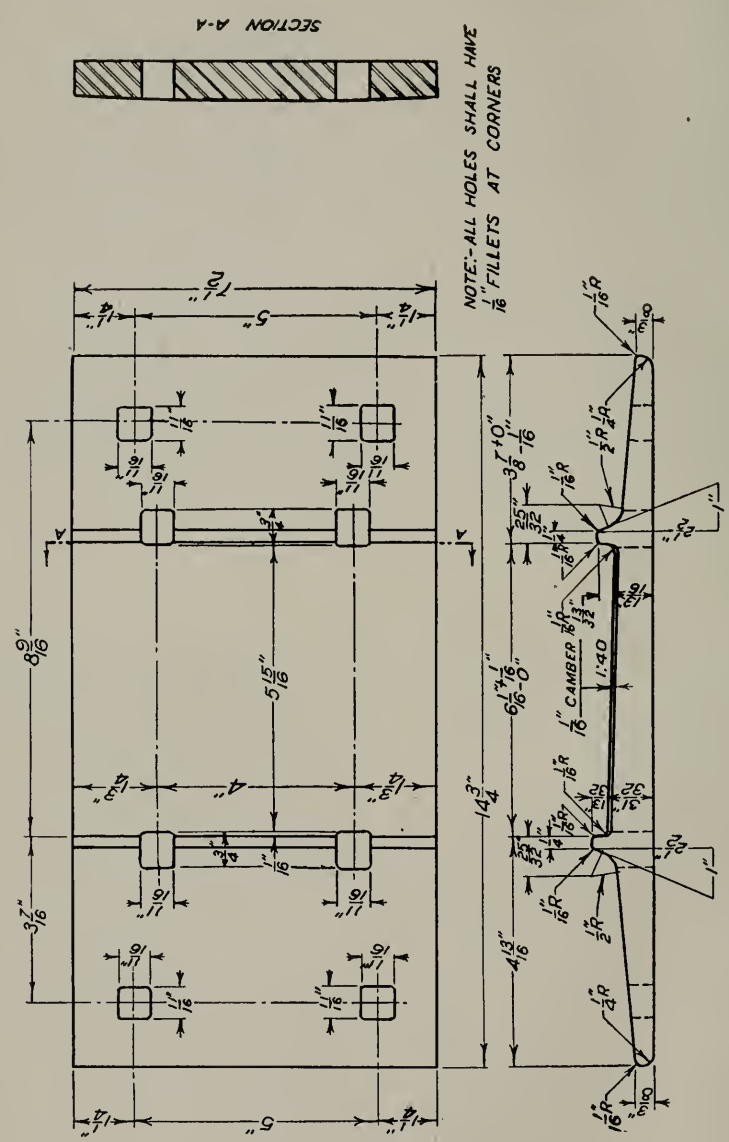


Fig. 3.—Plan T.M.831 Test Tie Plate for 131-lb. Rail.

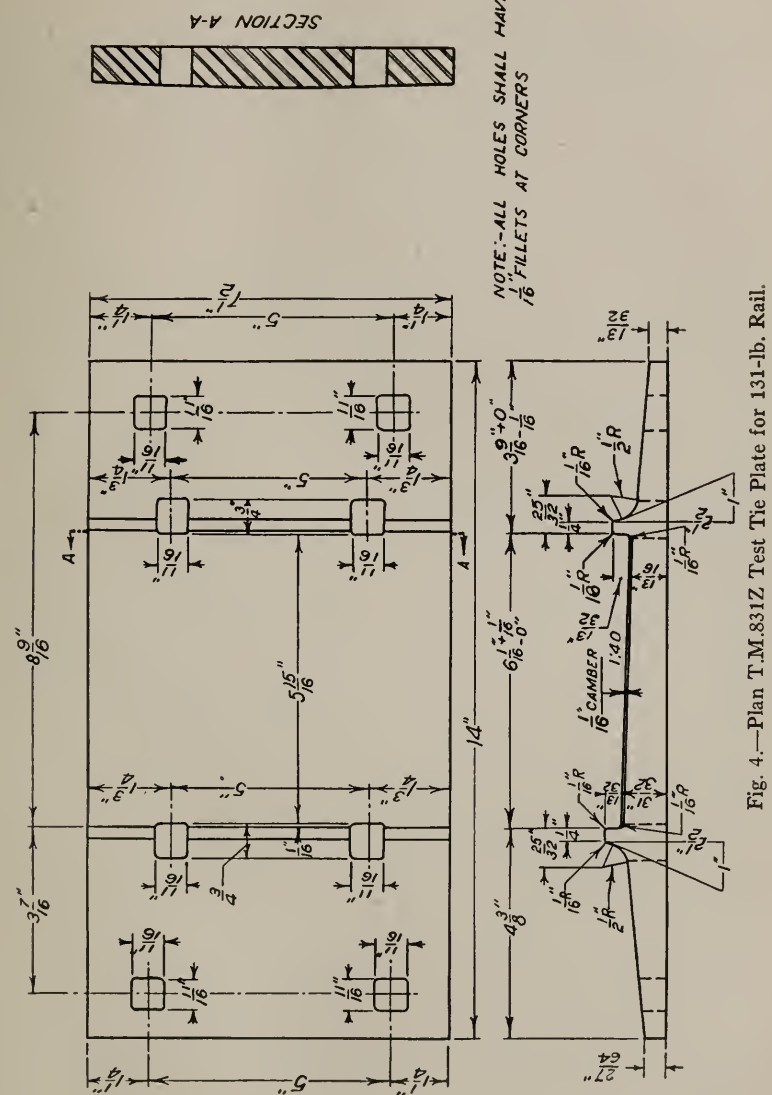


Fig. 4.—Plan T.M.831Z Test Tie Plate for 131-lb. Rail.

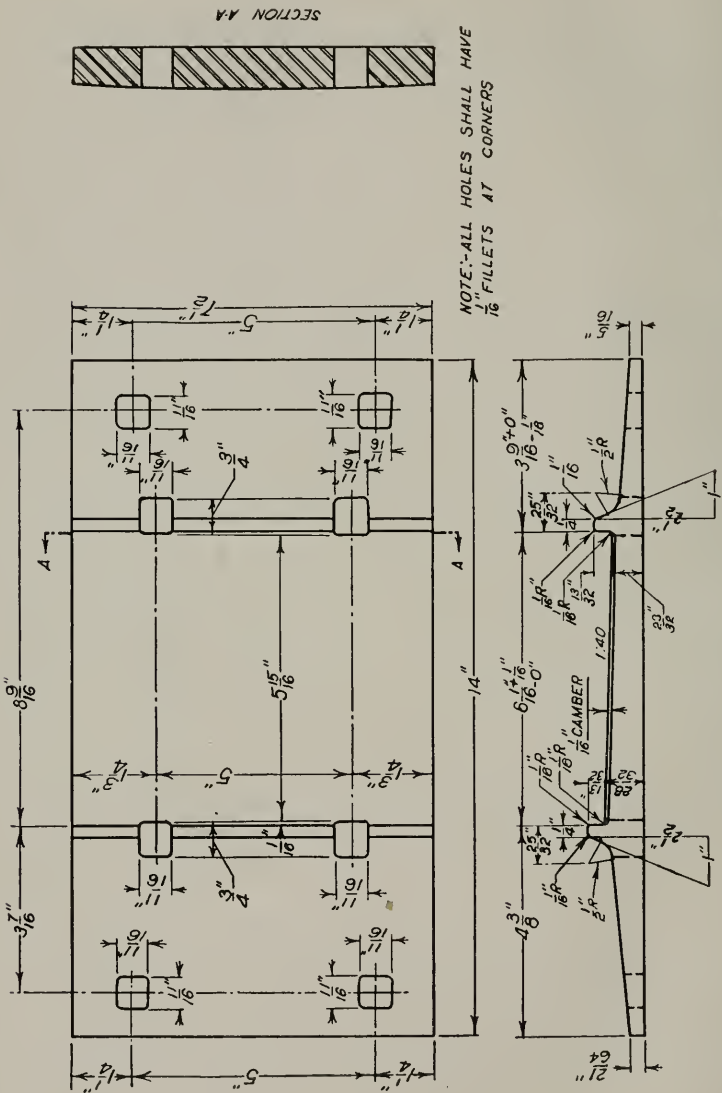


Fig. 5.—Plan T.M.831Y Test Tie Plate for 131-lb. Rail.

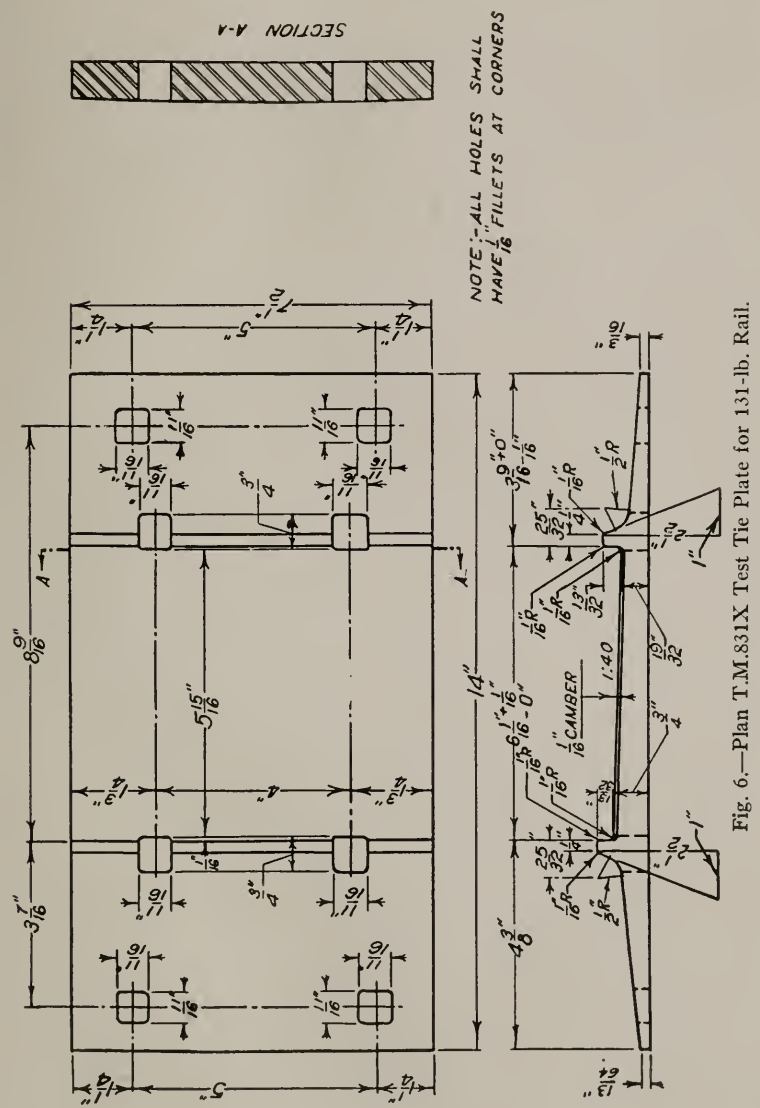


Fig. 6.—Plan T.M.831X Test Tie Plate for 131-lb. Rail.

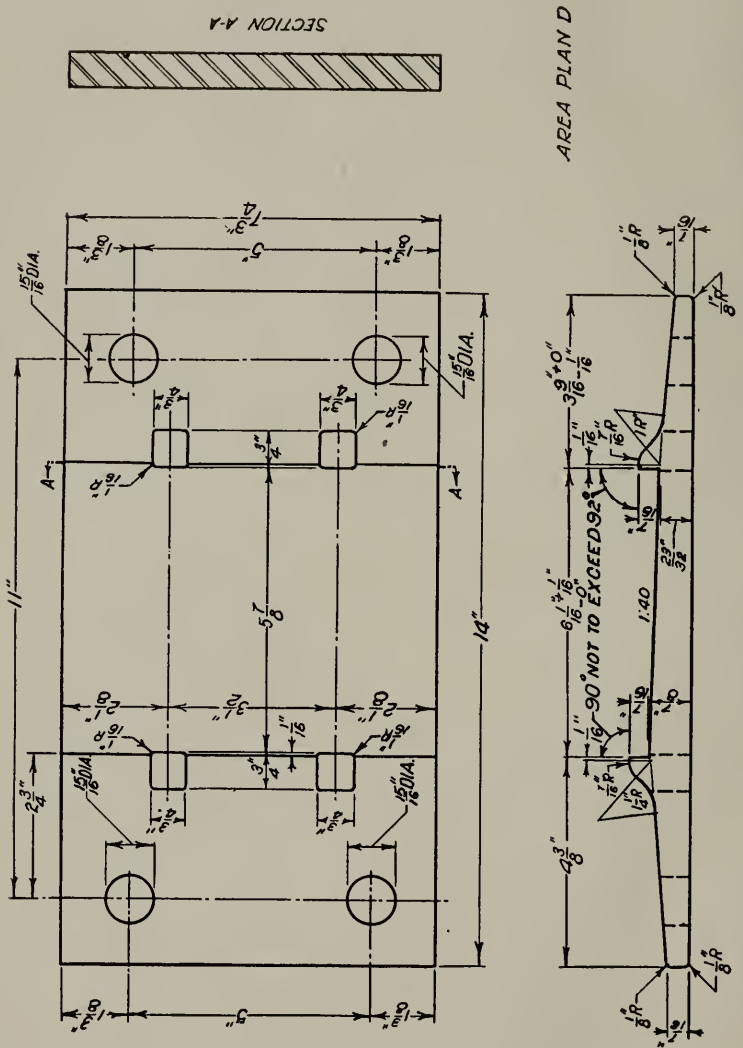


Fig. 7.—Plan T.P.-420 Test Tie Plate for 131-lb. Rail.

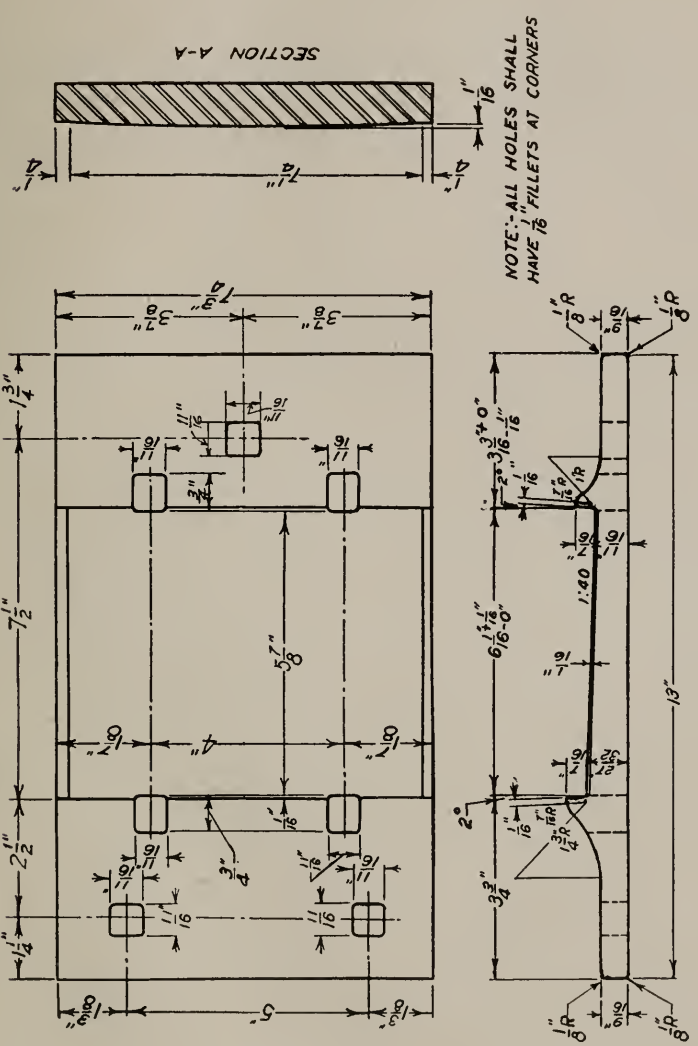


Fig. 8.—AREA Plan No. 5 Test Tie Plate for 131-lb. Rail.

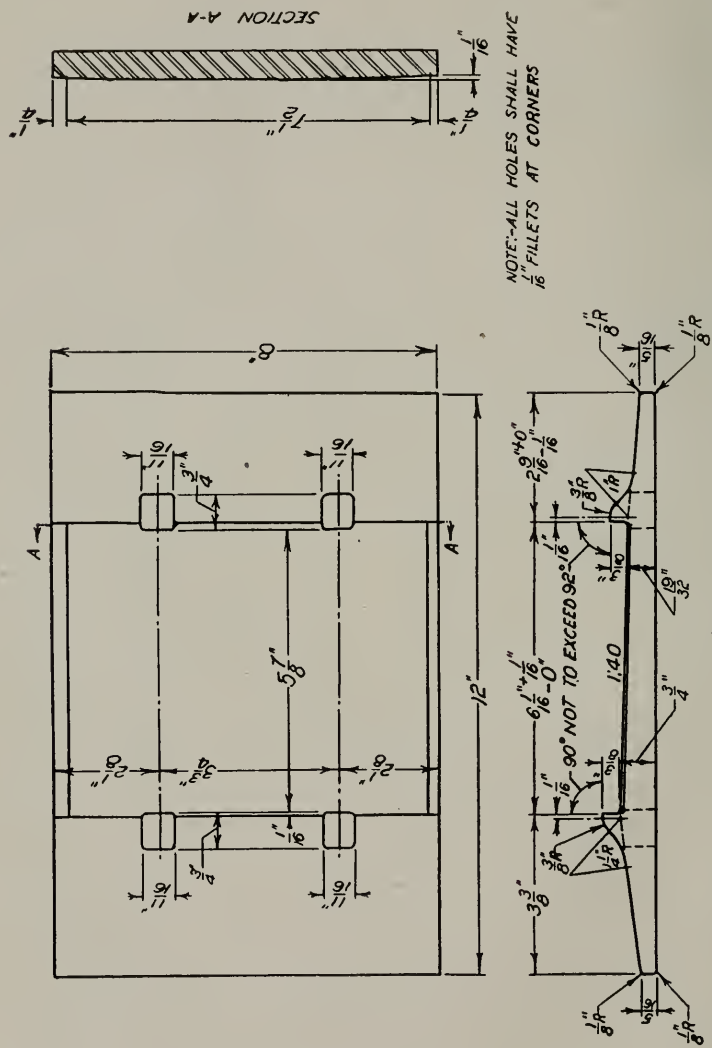


Fig. 9.—Plan T.P.-405 Test Tie Plate for 131-lb. Rail.

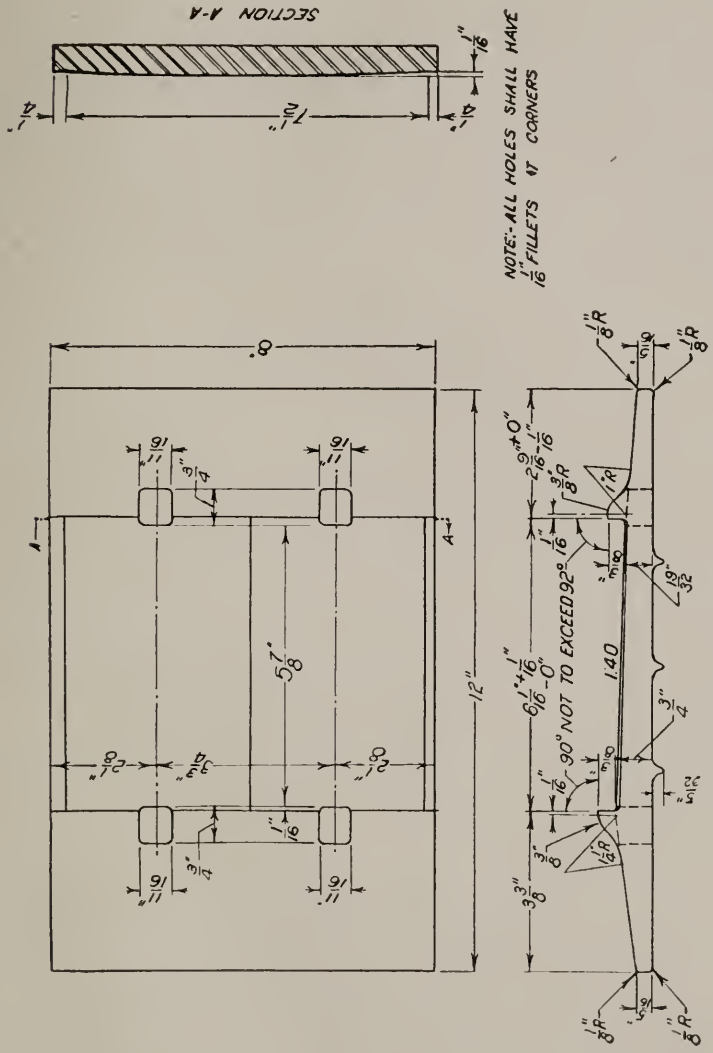


Fig. 10.—Plan T.P.-405-A Test Tie Plate for 131-lb. Rail.

Stress Measurement Schedules

It was necessary to determine upon a manner of selecting individual tie plates for the stress measurements so that comparable data would be obtained for the different designs of tie plates. Tests made in the past had shown that a considerable variation in the load taken by successive ties is to be expected in actual track conditions and this would, of course, have an appreciable influence upon the measured stresses. In addition, differences in bearing conditions of tie plates on the tie and rail base on the tie plates might be expected to considerably influence the measured stresses. It was also evident that the tie plates selected should be far enough from the joints to eliminate the influence of joint impact. Stresses in all of the plates could not be measured under the same locomotive and cars, so that a factor of difference in loading conditions must be anticipated. All in all, it was obvious that stress measurements must be made on several tie plates of each design for a considerable number of train movements in order to arrive at average stress values which would be at all representative of the effect of tie plate design.

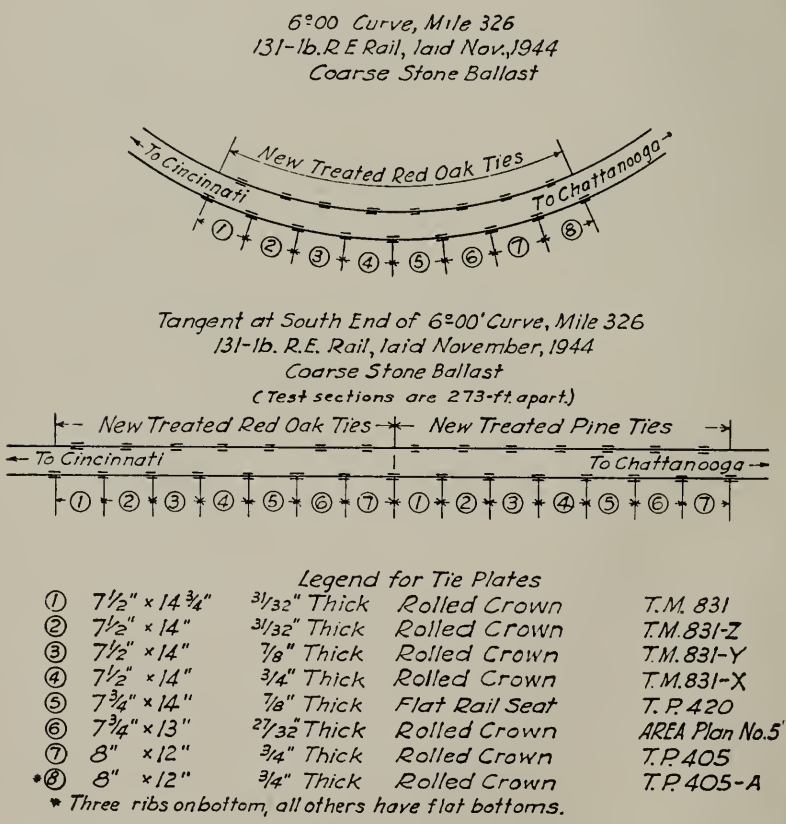
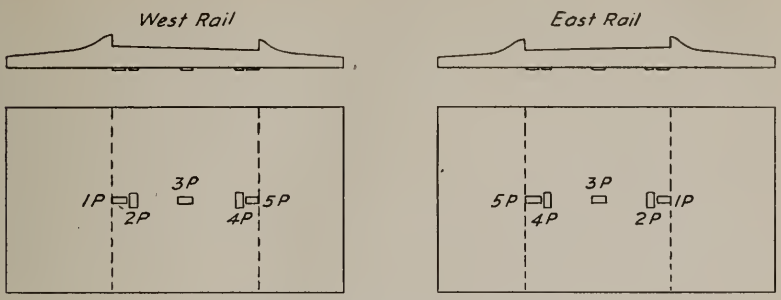
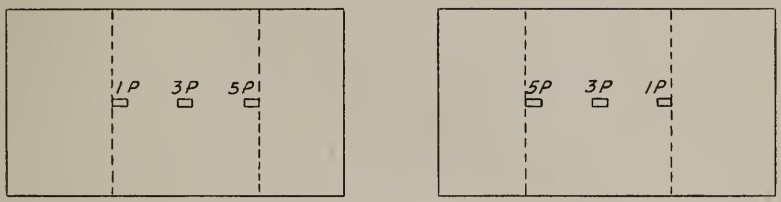


Fig. 11.—Tie Plate Test Installations on Southern Ry. System (C.N.O.&T.P.Ry.) Near Chattanooga, Tenn.



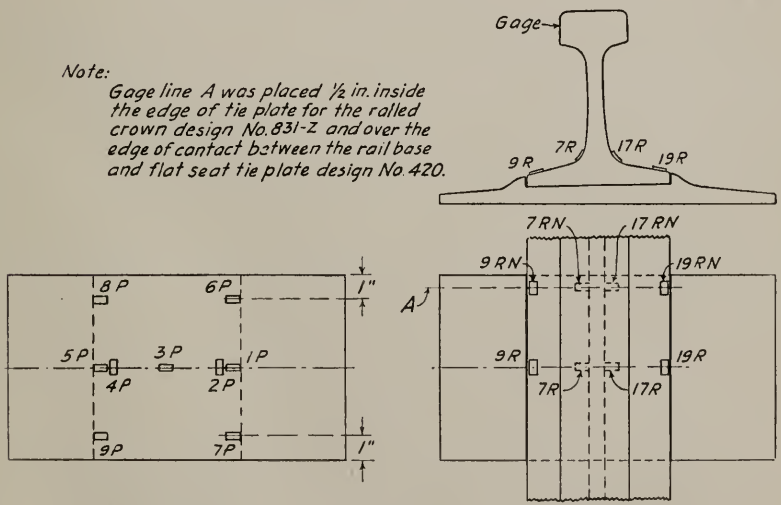
Near North Quarter - Panel Point
Two Tie Plates on the Same Tie for the Curve



Near South Quarter - Panel Point
Two Tie Plates on the Same Tie for the Curve
Note. Test on Tangent Track Omitted the Tie Plates Under the East Rail

Gage Position for 12 Tie Plate Stress Schedules

Note:
Gage line A was placed ½ in. inside the edge of tie plate for the rolled crown design No. 831-Z and over the edge of contact between the rail base and flat seat tie plate design No. 420.



Tie Plate Gages
Rail Gages
Gage Position for Six Rail and Tie Plate Stress Schedules

Fig. 12.—Gage Positions for Stress Measurements.

The time and expense involved in applying the stress gages made it necessary to give considerable attention to locating them on the tie plates in the most effective manner. Previous stress measurements conducted in the laboratory (see AREA Proceedings, Vol. 45, 1944, page 376) had shown that the location of maximum stress in the tie plate was near each edge of the rail base. It was also found that a gage location on the bottom of the tie plate directly under the center of the rail base was very significant in indicating the uniformity of distribution of the bearing pressure lengthwise of the plate. These locations are designated in Fig. 12 as positions 1–P, 3–P and 5–P. The gages were applied in this manner to one tie plate under the outer and inner rails of the curve and under one rail only of the tangent track in test panels 1 to 7, inclusive, on the treated hardwood ties on both curved and tangent track. On one additional tie plate under each of these same test rails two additional gages, designated 2–P and 4–P, were placed to measure the transverse bending stress in the tie plate in a direction parallel with the rail base and just inside each edge of the rail base. On the treated pine ties, gages were placed on two tie plates under the west rail of test panels 2 and 5 only in the manner just described.

It was also desired to make definite stress measurements to study the relative effects of the type of rail seat provided on the tie plate on the stresses within the tie plate and the localized stresses in the lower portion of the rail. Tie plate designs 831–Z and 420 were included in the test for this purpose, design 420 placed in panel 5 having a flat rail seat and design 831–Z placed in panel 2 having a rolled circular crown rail seat. Accordingly, one tie plate of each of these two designs was selected on the inside and outside rail of the curve and under the west rail of tangent track on the hardwood ties for special stress measurements. For these stress measurements the gages were located on the tie plate to determine whether there was any substantial difference in the stress pattern between the flat and rolled circular crown rail seat due to the so-called wave motion of the rail. Gages were located in the lower rail fillets and along the outer flanges of the rail base over the tie plate bearing to determine the amount of localized stresses in the rail base with special regard to any differences between the flat seat and rolled circular crown plates. Special attention was given in locating gages over the edge of the flat seated tie plates to determine whether under the wave action of the rail there would be any tendency toward higher stresses in the rail base at this location than over the center of the plate. The location of the gages as above described is shown in Fig. 12.

In Fig. 13 are shown the two typical arrangements of three and five wire gages used on the tie plates prior to attaching the lead wires. Three tie plates with gages and leads attached and protected with petroleum wax are shown in Fig. 14. The middle tie plate had nine wire gages applied to its bottom for one of the schedules in which rail stresses were also measured.

In Fig. 15 the method used for chiseling out the groove in a tie to accommodate the wire gages and leads is shown. In this operation care was exercised to avoid disturbing the ties in the ballast. The rail spikes were lifted in six ties each way from the test tie to permit raising the rail without lifting the ties. The same tie plate was replaced on the tie and the spikes were driven in the same holes for the purpose of keeping all conditions the same as in normal track. The necessity for cutting grooves in the tie to accommodate the lead wires resulted in reducing the bearing area of the tie plate on the ties to some extent. However, it is not believed that this materially affected the tie plate stresses.

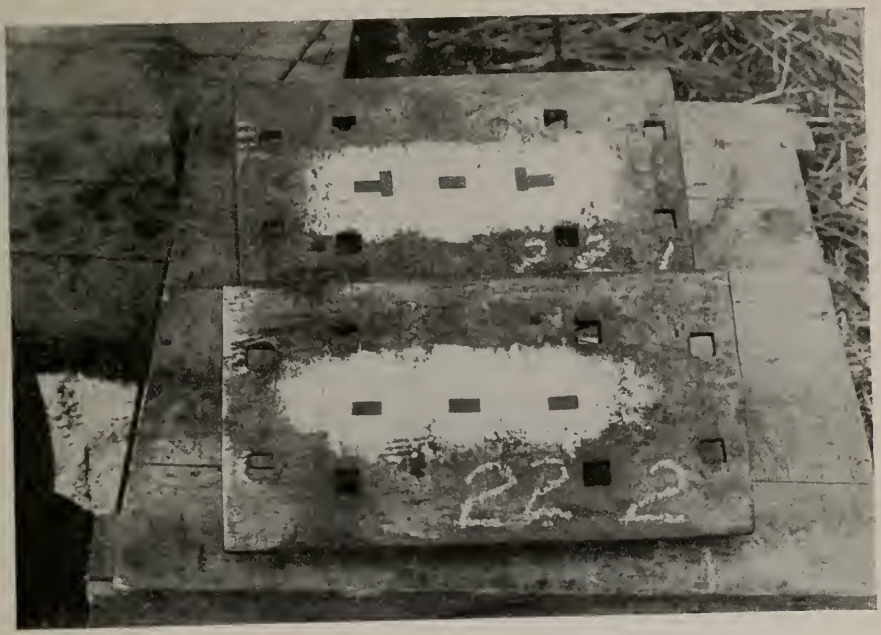


Fig. 13.—Bottom of Two Tie Plates Showing Wire Gages.

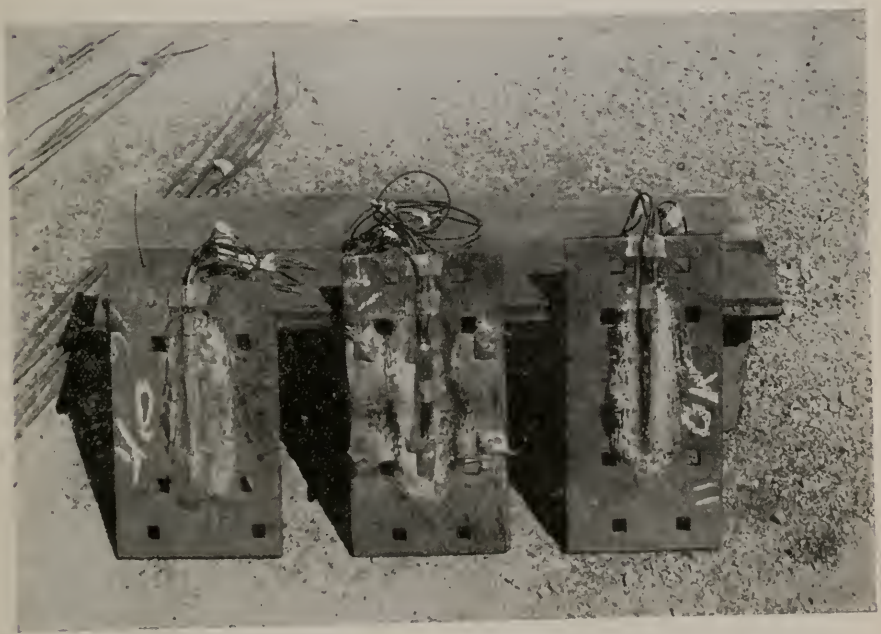


Fig. 14.—Bottom of Three Tie Plates Showing Completed Wiring and Waxing.

Fig. 15.—Cutting Groove in Tie for Wire Gages and Leads.

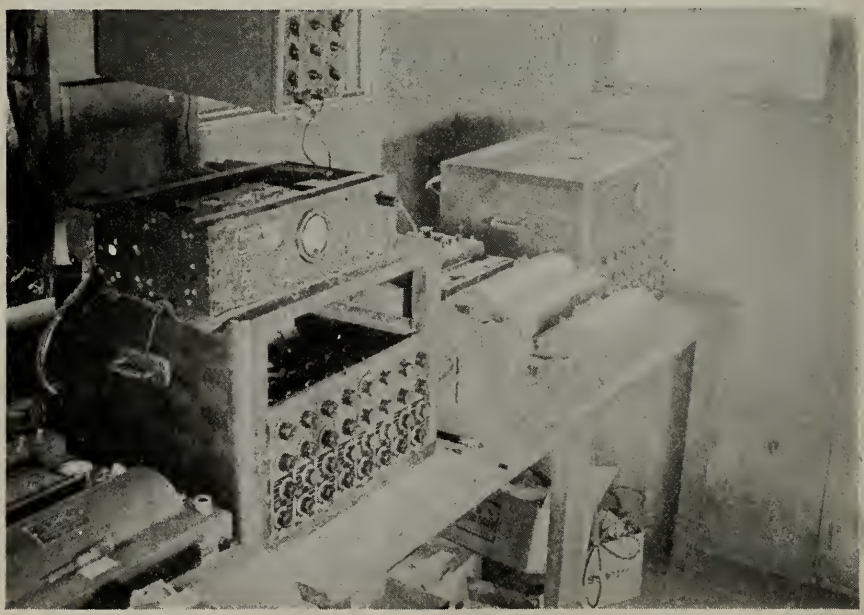


Fig. 16.—Oscillographs and Amplifiers in Test House.

Electrical Testing Apparatus

All stress measurements were made with the Baldwin–Southwark SR–4 electrical wire resistance strain gages, ½ in. in length, except that gages ¼ in. in length were used for the stress measurements in the rail fillets.

Prior to this year the testing equipment of the Engineering Division research staff included only one six-channel magnetic accelerometer amplifier which had been modified to operate with the wire gages. In order to conduct the field stress measurement tests programmed for this year and other investigations requiring the recording of simultaneous stresses at a larger number of gage positions, new amplifiers were obtained. Last year the apparatus on the market was found to be unsuitable for the purpose and the instrument manufacturers could not furnish specially built amplifiers to meet the requirements in time for this year's tests. Accordingly, two 8-channel wire gage amplifiers with self-contained power supplies, and two spare channels, were developed by H. C. Roberts, electrical assistant and built by W. M. Heilman, electrician, both of the research staff. This also involved the design and construction of the carrier current and regulated direct current power supply for each 8-channel unit. The new design greatly reduced the size and weight of the apparatus and the amount of power required for its operation. All parts were standard items although some substitutions were made where the most suitable parts were not available.

The amplifiers are of the carrier type and operate with carrier frequencies from 2000 to 5000 cycles per second. Stress frequencies can be recorded up to 1000 cycles per second. The input circuits are suitable for use with cables as long as 400 ft. and the output is suited to recording on magnetic oscillographs. A phase-discriminating rectifier was incorporated in the output stage so that no galvanometer deflection occurs until stress is present; the direction of stress is then indicated by the direction of deflection.

The simultaneous recording of stresses at 16 gage positions was effected by means of two 12-element oscillographs operating from a single remote control. Primary power of 110 volts, 60 cycles, for operating all equipment was furnished by a 2500-watt Homelite gasoline engine-driven generator unit. A view of the oscillographs and the new electric gage amplifiers set up in the test house is shown in Fig. 16.

One of the oscillograph records covering the stresses measured in two of the rolled circular crown tie plates of design No. 831–Z in panel 2 of the tangent test section with creosoted pine ties is reproduced in Fig. 17. The upper five traces show the strains measured in the first tie plate reached by the train while the lower three traces indicate the strains in the second tie plate. At the top of the oscillogram the location of the locomotive and car wheels is shown for the first tie plate and the dotted construction lines indicate the method of reading the stresses under the engine truck.

It will be of interest to observe that the stresses under the Mikado (2–8–2) locomotive in the tie plate at Location 1 are larger than the corresponding values in the tie plate at Location 2. This condition results because the two tie plates receive different loads due to the variations in the conditions of rail and tie support. This condition was found to exist generally throughout the test and as previously stated, made it necessary to average stress measurements for several different tie plates of any one design to obtain representative stress values.

Discussion of Test Data

Tie Plate Stresses—Hardwood Ties

The maximum stress at any gage location recorded under the locomotive, tender and cars separately, was considered to be the most significant stress value to use for

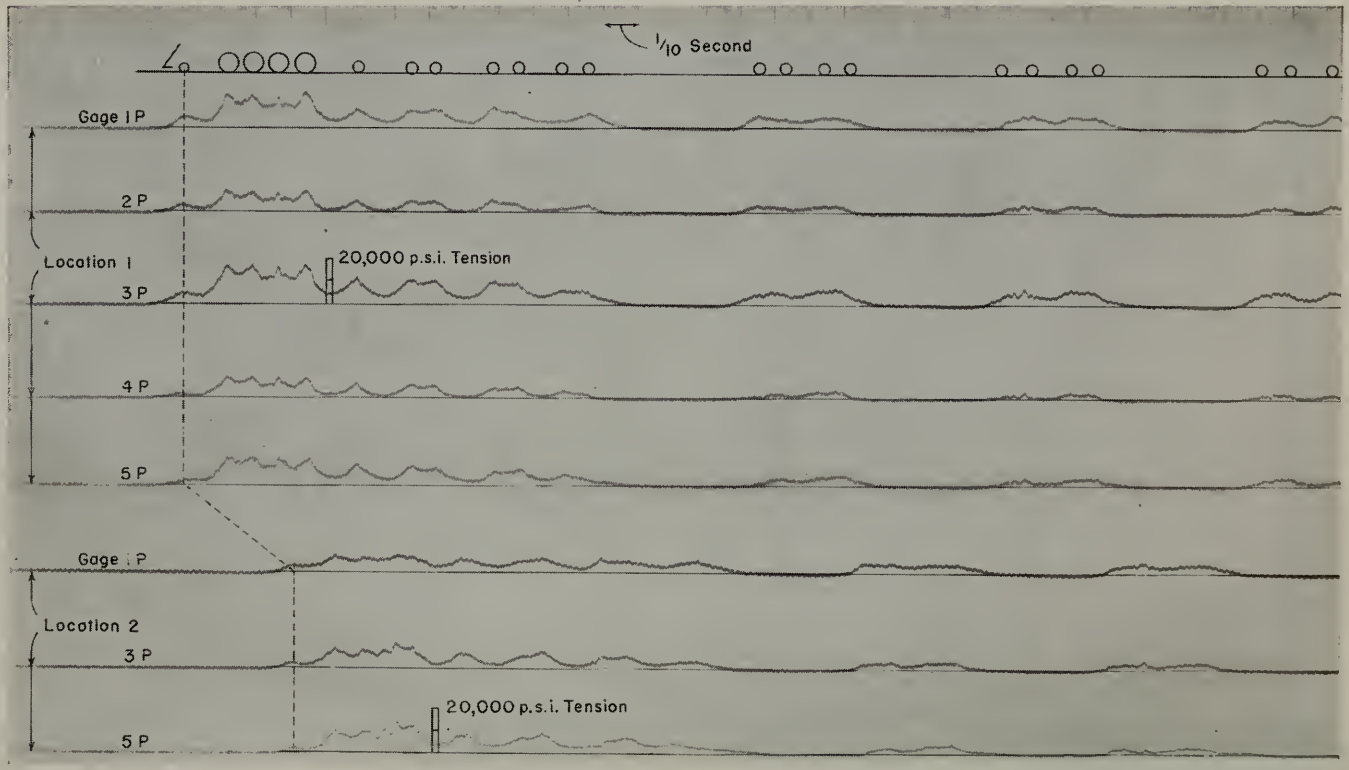


Fig. 17.—Oscillograph Record of Stresses in Two Tie Plates of No. 831–Z Design Run No. 218, Locomotive 6350 (2–8–2) Southbound Troop Train, Speed 50 mph. (Tangent Track).

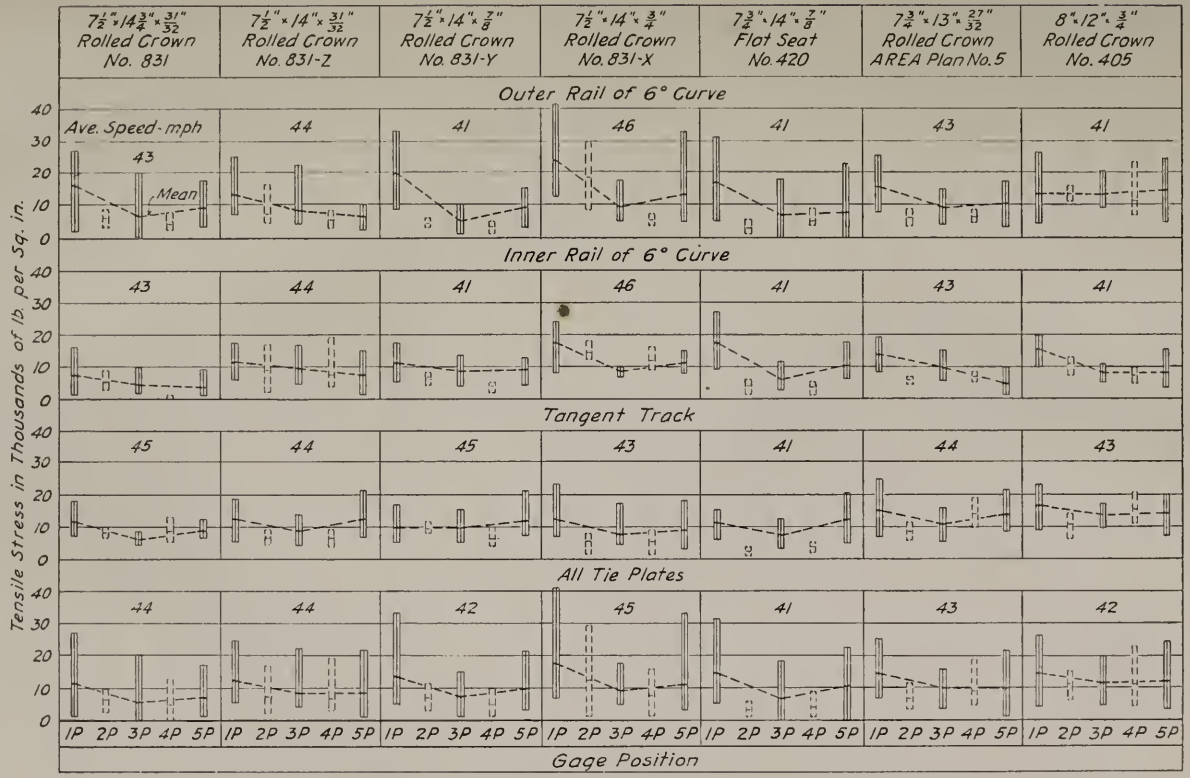


Fig. 18.—Summary of Maximum Flexural Stresses Measured in the Bottom Surface of Seven Designs of 131-lb. Tie Plates Under Locomotives (Creosoted Red Oak Ties).

each test run. Stresses were measured for 8 to 15 runs for each tie plate tested, thus providing 8 to 15 maximum stress values for each gage position.

A summary of the maximum tie plate stresses measured under the locomotives in the outer and inner rails of the 6-deg. curve, tangent track and for all tie plates of each of the seven designs on creosoted oak ties is given in Fig. 18. In this figure each subdivision is based on the stresses measured in two tie plates of the same design for each rail on the curve and tangent track, except the rolled circular crown design No. 831–Z and the flat seat tie plate No. 420 include three tie plates. The summary in the lower tier of the figure covers nine tie plates for the two designs above mentioned and six for each of the other five types of tie plates. The top and bottom of each bar in Fig. 18 represent the single highest and lowest maximum stress, respectively, and the dotted line between the above values is the mean of the maximum stresses. The dotted average lines connect only gages 1–P, 3–P and 5–P which registered the longitudinal bending stress along the center line of the bottom of the plates, while gages 2–P and 4–P indicated the stress values transversely to the tie plates.

It will be observed from study of Fig. 18 that the variation in maximum stress values at any one gage location for succeeding runs is very large, indeed. Accordingly, in making comparisons between the different designs of tie plates more dependence should be placed upon the mean values. However, the maximum stresses as indicated by the top of the bars in the figure are significant in indicating whether an occasional stress may be developed of sufficient magnitude to bend the tie plate.

It will be observed that generally speaking the stress values are higher for all designs of plates in the tests made under the outer rail of the 6-deg. curve. This is undoubtedly due to the fact that for practically all test runs the operating speed was in excess of the speed of superelevation, causing more load to be thrown upon the outer rail. For the test, both on the outer rail and inner rail of the curve, it will be observed that the stresses were generally higher at gage location 1–P under the outer edge of the rail base than they were under the inner edge of the rail base at gage 5–P. In the tests under the tangent track stresses were higher under the inner edge for several of the designs.

The measured stresses at gage 3–P are generally below the mean of the measured stresses at 1–P and 5–P. As previously stated, this relative stress value at 3–P is important in indicating the uniformity of bearing pressure of the tie plate on the tie, a low relative value at 3–P indicating that the bearing pressure of the tie plate on the tie is greatest under the rail base and decreases toward the ends of the tie plate; a high relative value of stress at 3–P indicating a more uniform distribution of bearing pressure of the tie plate on the tie throughout the length of the tie plate, or perhaps even a greater bearing pressure near the ends of the tie plate than near its mid-length. This latter condition of high bearing pressure at the ends of the plate may be expected after tie plates have been in service for a considerable period of time and the wood fibers have become deteriorated near the mid-length of the plate where the bearing pressures are initially more severe. Generally speaking, the relative stress values of 1–P, 3–P and 5–P, measured in the tests indicate that the bearing pressure of the test tie plates on the ties is still greater near the mid-length of the plate than at the ends.

Unfortunately, the variation in stress conditions from plate to plate and with different trains was found to be so great that with the relatively small number of tie plates tested, it is impossible to make very definite comparisons with respect to the features of tie plate design included in the test. As previously stated, gage locations 1–P and 5–P are most significant with respect to the bending stress developed lengthwise of the tie plate. It will be observed in the diagrams summarizing all tie plates tested, in Fig. 18, that for the 14-in. tie plates No. 831–X, No. 831–Y, and 831–Z, there is a

progressive decrease in tie plate stress as the thickness of the plate is increased from ¾ in. to $\frac{31}{32}$ in. Also, for the $\frac{31}{32}$-in. plate the relative stress value at 3–P is higher, indicating that the thicker plate is producing a more uniform pressure distribution on the tie throughout the length of the plate. The variation in measured stresses was such that the additional ¾ in. in the length of the plate in design No. 831 could hardly be expected to influence the average results.

With respect to the bending stresses lengthwise of the plate there is no appreciable difference between tie plates No. 831–Y and No. 420, which plates are similar except for the difference in type of rail seat. It would be anticipated that the measured bending stresses in the 13-in. plate (Plan No. 5) and in the 12-in. plate (No. 405) would correspond to those of the 14-in. plate (No. 831–Z) because of the respective ratios of thickness under the outer shoulder to the length of the outer toe. Actually, the measured stresses for these two plates were somewhat higher than for the 14-in. plate, No. 831–Z. but not significantly so, considering the number of plates tested. From the standpoint of bending stresses lengthwise of the plate, the 14-in. plate (No. 831–Z) and the 14¾-in. plate, (No. 831) gave the most favorable bending stresses.

Generally speaking, the measured stresses at gages 2–P and 4–P, which represent the bending transversely of the tie plates, are considerably lower in value than the bending stresses lengthwise of the tie plate. In general, these transverse stresses assume little importance. However, it should be noted that the transverse bending stresses for flat seated tie plate No. 420 as shown in the summary diagram including all tie plates tested, are lower than for the designs of tie plates with the rolled circular crown.

Table 2 is a summary of the maximum tie plate stresses measured under the tenders and cars, and was prepared in a manner similar to Fig. 18 except that the results have been presented in tabular instead of graphical form and only the data for all tie plates are given. It will be observed that the average maximum stresses for both the tenders and cars are somewhat lower than those measured under the locomotives.

Description of Tie Plate and Designation		Speed m.p.h.	All Tie Plates									
			1P		2P		3P		4P		5P	
			Tend.	Cars	Tend.	Cars	Tend.	Cars	Tend.	Cars	Tend.	Cars
7½"x14 3/4"x 31/32" Rolled crown No. 831	High	44	20.5	17.3	6.8	17.2	18.8	11.2	9.2	8.8	13.3	10.2
	Ave.		8.3	7.0	4.1	4.0	3.6	2.7	3.2	2.2	4.6	3.3
	Low		0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0
7½"x14"x 31/32" Rolled crown No. 831-Z	High	44	20.0	15.9	8.4	10.0	16.3	12.5	10.4	9.2	15.2	12.8
	Ave.		7.5	6.3	4.4	3.3	5.4	4.3	4.4	3.5	4.3	3.8
	Low		1.2	0.0	0.0	0.0	1.1	0.7	0.8	0.4	0.0	0.0
7½"x14"x 7/8" Rolled crown No. 831-Y	High	42	20.4	17.4	11.2	7.2	9.9	10.7	4.6	4.9	9.2	18.8
	Ave.		8.0	7.8	4.1	3.2	4.8	4.1	2.6	1.6	4.7	4.4
	Low		1.2	2.0	0.8	0.0	1.1	0.8	0.8	0.0	0.0	0.0
7½"x14"x 3/4" Rolled crown No. 831-X	High	45	36.6	21.5	21.7	17.1	14.1	10.7	9.6	11.6	14.8	21.1
	Ave.		11.4	9.8	9.9	8.7	6.0	4.7	4.8	5.6	5.7	4.6
	Low		2.2	1.5	0.8	0.4	1.1	0.7	0.8	0.4	0.8	0.0
7 3/4"x14"x 7/8" Flat Seat No. 420	High	41	23.7	22.9	4.0	4.8	13.3	10.6	6.5	4.8	12.9	13.3
	Ave.		9.7	8.7	2.2	1.8	4.0	3.4	2.5	2.1	5.5	4.4
	Low		1.6	1.2	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0
7 3/4"x13"x 27/32" Rolled crown Also Plan No. 5	High	43	20.[illegible]	23.4	8.4	7.6	12.8	14.8	12.5	16.7	16.8	18.8
	Ave.		10.3	9.9	5.4	5.0	6.7	6.5	5.5	4.7	4.6	3.7
	Low		1.6	3.3	2.8	1.5	1.6	1.6	1.2	0.0	0.0	0.0
8" x 12" x 3/4" Rolled crown No. 405	High	42	20.1	25.4	12.2	13.3	15.2	14.0	18.0	20.8	17.6	20.2
	Ave.		8.9	9.9	7.8	8.3	8.3	8.2	7.8	8.0	6.5	6.5
	Low		0.7	0.7	1.9	4.0	3.0	2.0	2.0	2.3	0.0	0.0

TABLE 2.—SUMMARY OF MAXIMUM STRESSES MEASURED IN ALL TIE PLATES OF EACH DESIGN UNDER TENDERS AND CARS. CREOSOTED OAK TIES

(Units of 1000 lb. per sq. in. Tension)

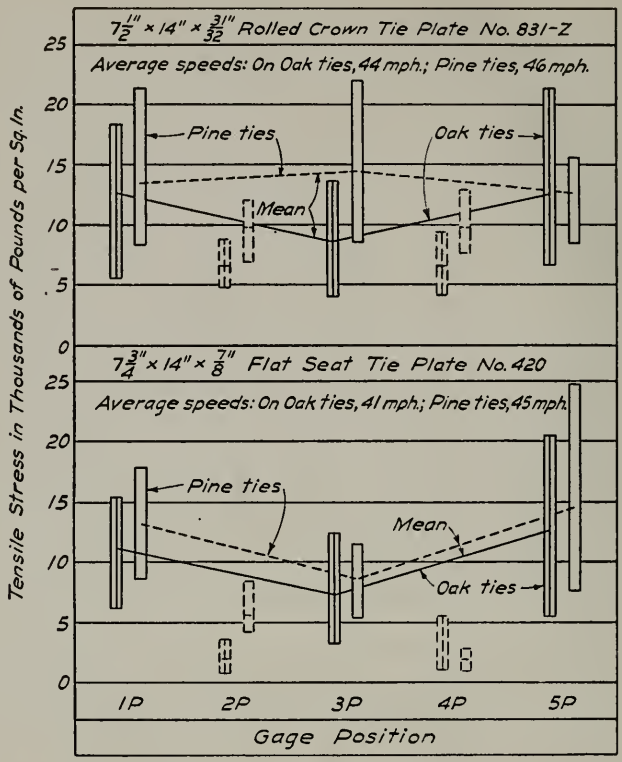


Fig. 19.—Comparison of Maximum Stresses in Two Designs of 131-lb. Tie Plates Measured Under Locomotives in Tangent Track with Creosoted Oak and Pine Ties.

Tie Plate Stresses—Softwood Ties

Because of the amount of testing time that would be required, tests were not made on all designs of plates in the tangent track test on new treated pine ties, but stresses were measured in two tie plates in each of the tangent panels 2 and 5, and this afforded a direct comparison with the performance of the same designs of plates on the hardwood ties in the adjoining test section. These stress measurements were made on designs No. 831–Z and 420, and a comparison of the relative results for these two types of tie plates on treated pine and treated oak ties is shown in Fig. 19. The measured stresses for plate No. 831–Z with the rolled circular crown is shown at the top of this figure. The maximum bending stresses lengthwise of the plate were found to be approximately the same on both the oak and pine ties. The relative stress at gage 3–P is much higher for the pine tie, indicating a concentration of bearing pressure between tie plate and tie at the ends of the plate. However, in view of the fact that this same condition is not reflected in the tests with the flat seated tie plate, it seems that no significance should be attached to this. In the stress measurements for the flat seated tie plate shown in the lower portion of Fig. 19, the measured stresses were found to be somewhat higher on the pine ties. It is to be expected that tie plate stresses would be somewhat higher on softwood ties.

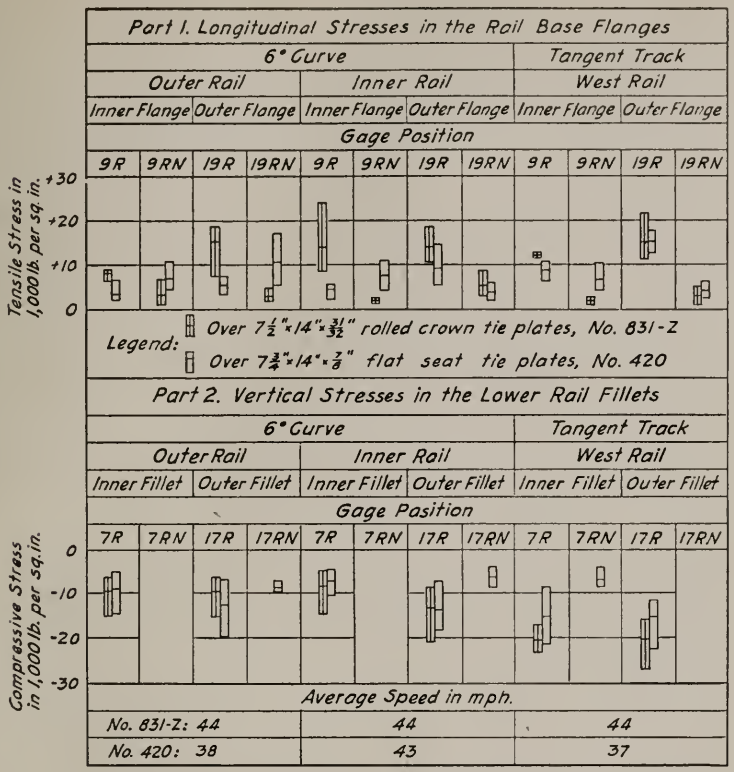


Fig. 20.—Maximum Stresses in 131-lb. RE Rail Measured Under Locomotives with the Rail Supported on Rolled Crown (831–Z) and Flat Seat (420) Tie Plates.

Localized Stresses in the Lower Fillets and Base of Rail

In Fig. 20 is a summary of the maximum stresses measured in the base flanges and lower fillets of 131-lb. RE rail at six locations on creosoted oak ties and over the rolled circular crown tie plate No. 831–Z and the flat seated tie plate No. 420. Part 1 covers the longitudinal tensile stresses measured in the base flanges and Part 2 gives a comparison of the compressive stresses in the lower rail fillets. The gage positions will be understood by referring to Fig. 12. The "R" gages were located on the rail over the longitudinal center line of the flat seat tie plates and over the center line of the contact area between the rail base and the rolled circular crown tie plate. Due to wear of the crest of the rolled circular crown and warping or twisting of the tie in the ballast the center of pressure is not always coincident with the longitudinal center line of the tie plate. The "RN" gages were located above the edge of contact between the rail base and the flat seated tie plate, and ½ in. inside of the edge of the rolled circular crown plate. Keeping in mind that the maximum stress in the rail base flanges occurs at the "R" position over the rolled circular crown tie plates and at either the "R" or "RN" position over flat seated plates, it will be observed that the mean maximum longitudinal

stresses in the rail base flanges over rolled circular crown tie plate No. 831–Z are higher than those over the 420 design, except that in the outer flanges of the rail in tangent track the average stresses are equal at gage position 19–R.

The percentage increase of the mean maximum longitudinal rail base stress for the rolled circular crown tie plate over that for the flat seat tie plate follows:

Location	*Percent*
Outer flange, outer rail	46
Inner flange, inner rail	88
Outer flange, inner rail	57
Outer flange, tangent rail	00

For the lower fillet compressive stresses (Part 2 of Fig. 20) the mean maximum stresses for the two designs of tie plates are of comparable magnitude on the curve and moderately smaller on tangent track over the flat seated tie plate.

These localized rail stresses, in general, are much lower than those found in other field tests. This is attributed to the lighter class of locomotives used and also to the fact that the operating speeds on the curved track were higher than those which would produce maximum localized stress conditions in the rail base.

Conclusions

Relative evaluation of certain important features of tie plate design such as length, thickness, and eccentricity can not well be made from the stress measurements. This can best be made from the measurements now in progress of the wear of ties under tie plates and of the amount of permanent bending of the plates after a sufficient service period has elapsed to make these measurements significant.

These stress measurements have confirmed, under actual track conditions, the results obtained in the laboratory with regard to localized stresses in the rail base flange and lower fillets. These localized stresses in both track and laboratory measurements have been found to be much higher over the rolled circular crown plate than over either the center or edge contact of the flat seated tie plate.

Further analysis of the stress measurements may be expected to furnish data on the maximum tie plate load developed in track for the types of locomotives tested, which will be useful for the purposes of tie plate design.

Acknowledgement

M. F. Smucker, assistant electrical engineer, was in direct charge of the field tests, and H. E. Durham, track engineer, analyzed the data and prepared the report under the general direction of G. M. Magee, research engineer. The committee desires to express its appreciation for the splendid cooperation and assistance rendered by the Southern Railway System in the original installation of the test tie plates and in the track work involved in making the stress measurements. The AAR furnished all the test tie plates and the railway furnished all labor and material for relaying the rail, renewing ties and resurfacing the track.

Report on Assignment 7

Welding of Manganese Castings in Special Trackwork Collaborating with Committee 27—Maintenance of Way Work Equipment

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This is a progress report presented as information. The report on the assignment this year consists of a description of the observed service performance of the special test castings on the Chicago, Milwaukee, St. Paul & Pacific Railroad at Mannheim, Ill., and of the specially welded frogs on the Toledo Terminal Railroad at Toledo, Ohio. The detailed program of the investigation and a description of the Milwaukee and Toledo Terminal test installations may be found in last year's report (Proceedings, Vol. 46, page 525) and in previous reports of the subcommittee.

Milwaukee Railroad Installation

By March 1945, all of the castings of the center panel except C–3 and C–8 were in such a condition that they could not be continued in service. Accordingly, this panel was removed and castings C–3 and C–8 were used to replace castings W–5 and W–8 of the west panel, which castings were also in bad condition.

On November 15, 1945 the measurements to determine the rate of wear and batter of the individual castings were repeated. These measurements have been taken periodically since the frogs were installed in November 1939, and are shown in Fig. 1 for the east panel which has not been welded, and in Fig. 2 for the west panel which was welded in November 1942. Corresponding measurements for the center panel may be found in last year's report.

Figs. 3 to 6, inclusive, are photographs of the test castings, showing their condition as of November 15, 1945 when the measurements were taken.

It will be observed in Fig. 1 that the wear of the point of the casting (A–4) and of the wing (D–3) has progressed at about the same rate except for the first few months of service. (See Proceedings, 1945, Vol. 46, p. 536, Fig. 10 for the locations of A–4 and D–3). Although the point wear has now progressed to about 0.4 in., almost half of this represents general wear of the running surfaces or at the fishing surfaces, and the actual batter of the point (represented by the difference between A–4 and the average of B1 and B7) varies from 0.22 to 0.27 in. for the various castings. Generally the eight unwelded castings of this panel have given about equal performance with respect to wear and batter. Castings E–1, E–4, E–6, and E–8 show some spalling of the point, and the turnout flangeways are rather badly cracked.

Generally speaking the performance of the unwelded castings in this panel has been much better with respect to spalling and chipping than that of most of the welded castings in the other two panels.

The condition of the castings in the west panel at the time of the November 15, 1945 measurements was as follows:

Castings W–1, which was welded with ¼-in. diameter nickel-manganese rod, was in good condition and the wear and batter (Fig. 2) progressed during the past year at only a little more than the normal rate.

Casting W–2 was cut with an acetylene torch before welding, the wing being ground before welding and the point being welded directly on the cut surface. The point was spalled on this casting (Fig. 3), but the wing was in good condition.

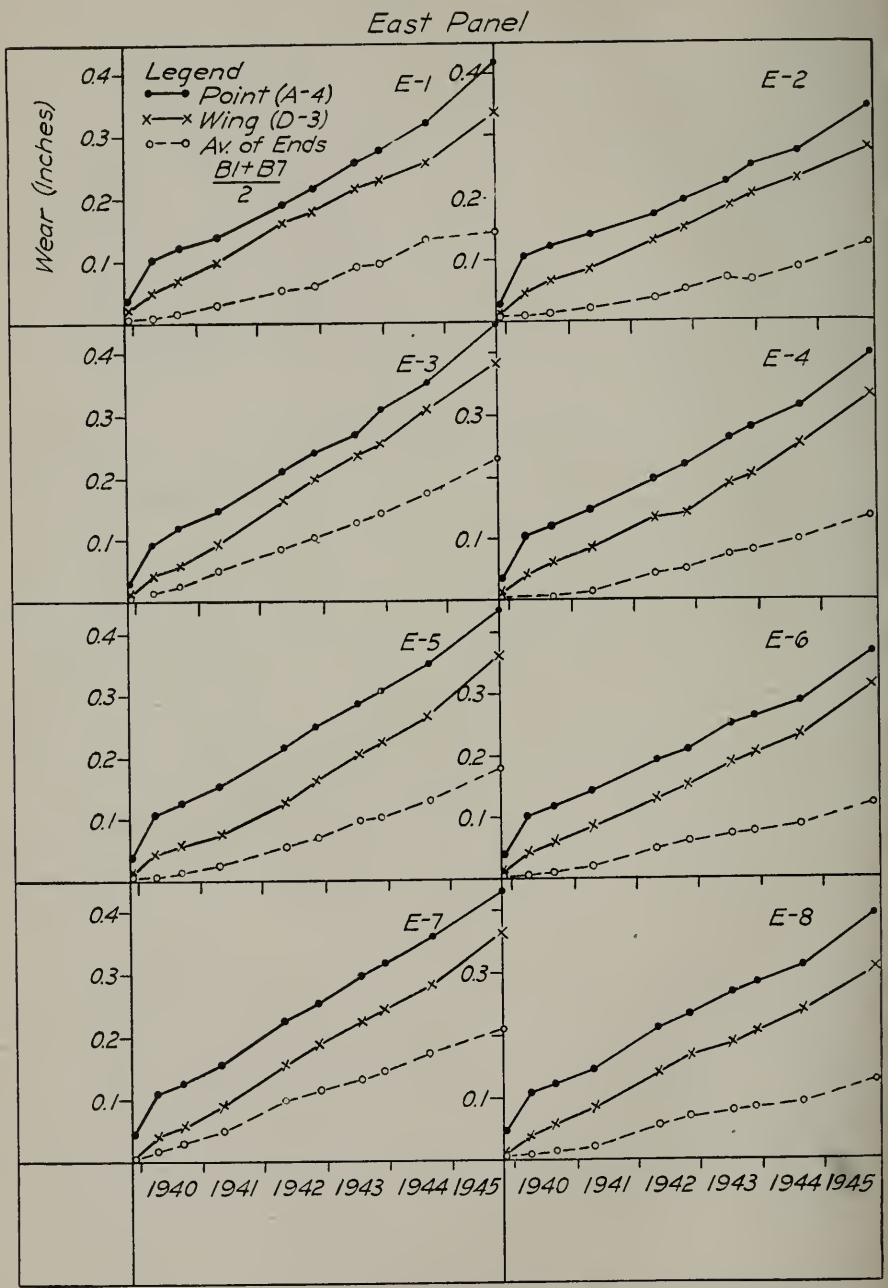


Fig. 1.—Wear Measurements—Special Tests Castings—Milwaukee Railroad Tests.

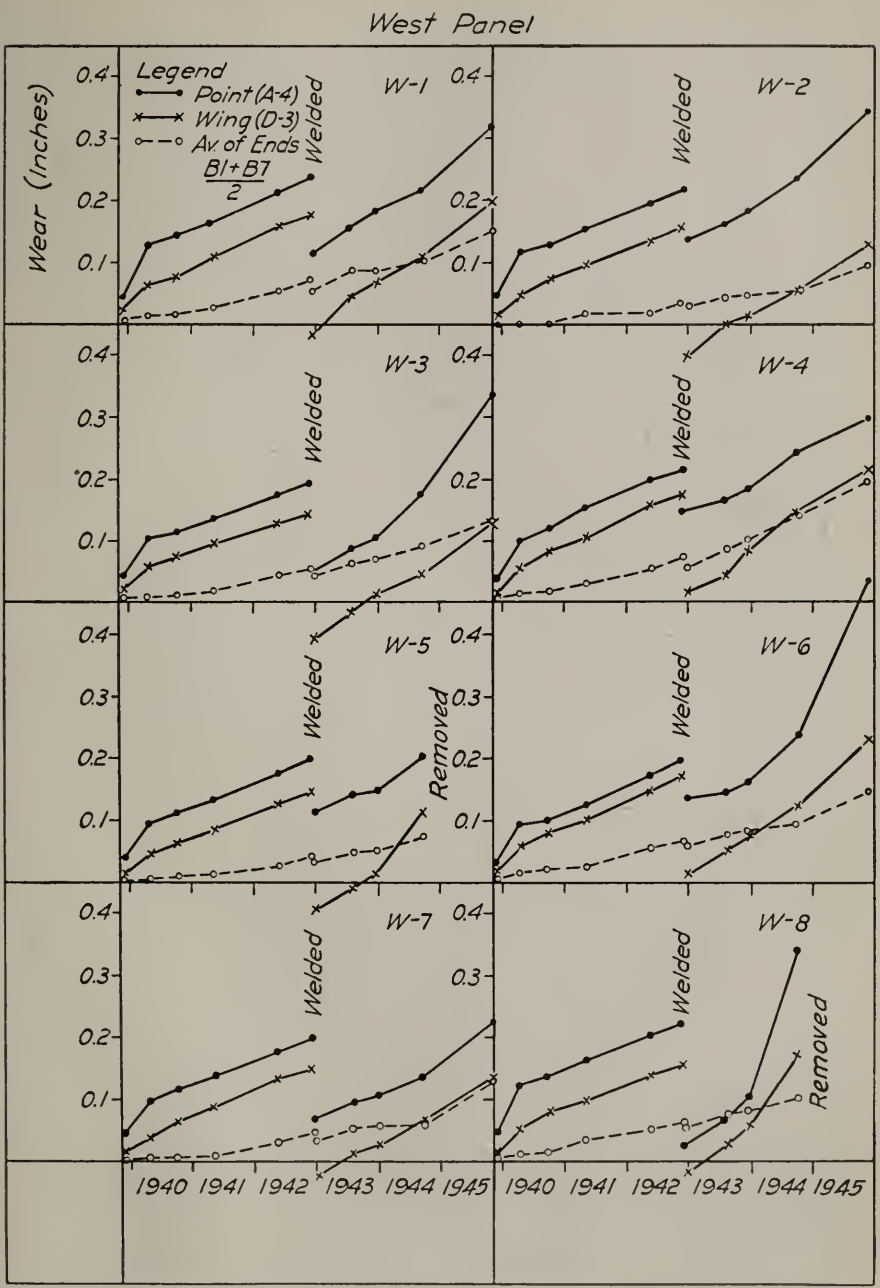


Fig. 2.—Wear Measurements—Special Tests Castings—Milwaukee Railroad Tests.

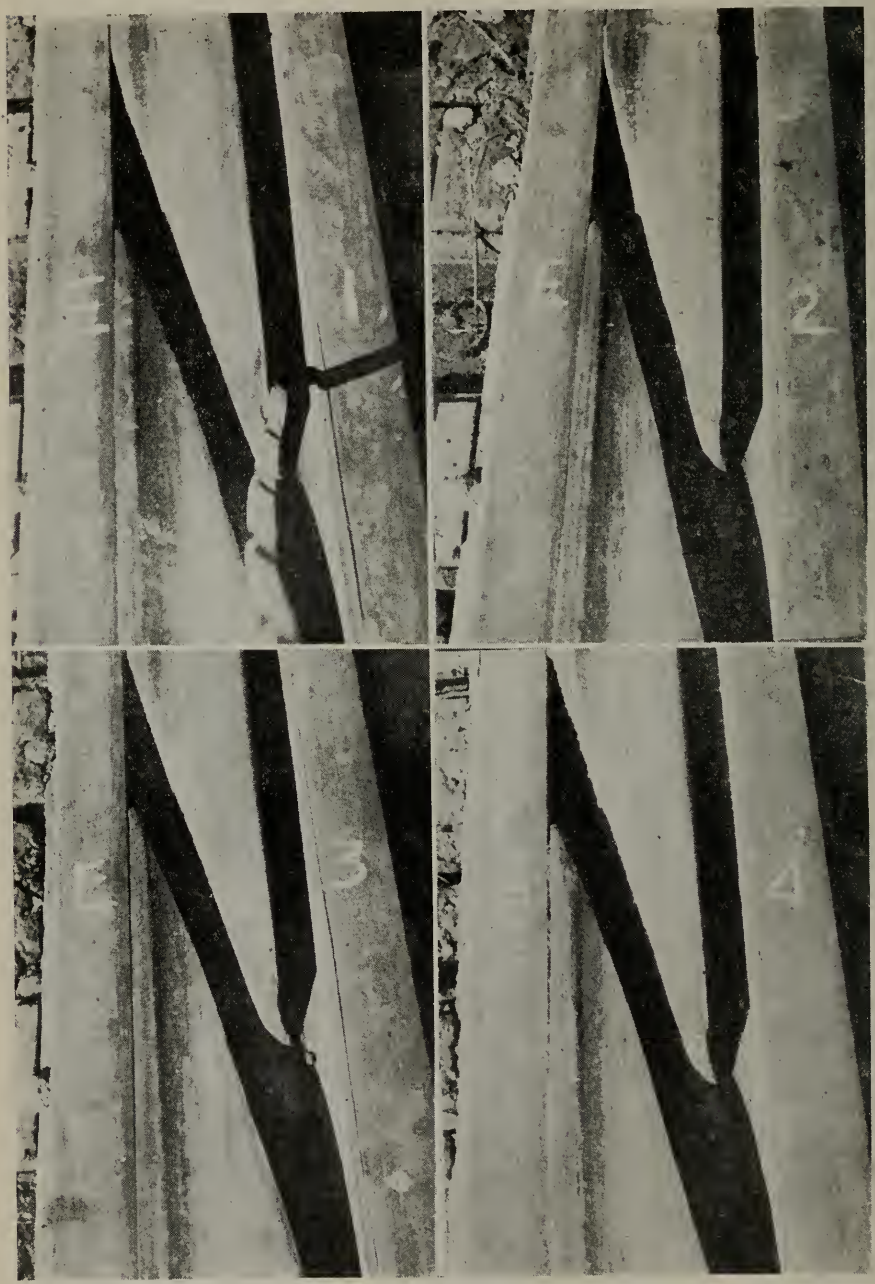


Fig. 3.—Views of Four Test Frogs of East Panel—Mannheim Test Installation—Chicago, Milwaukee, St. Paul & Pacific, Taken November 15, 1945. Not Welded.

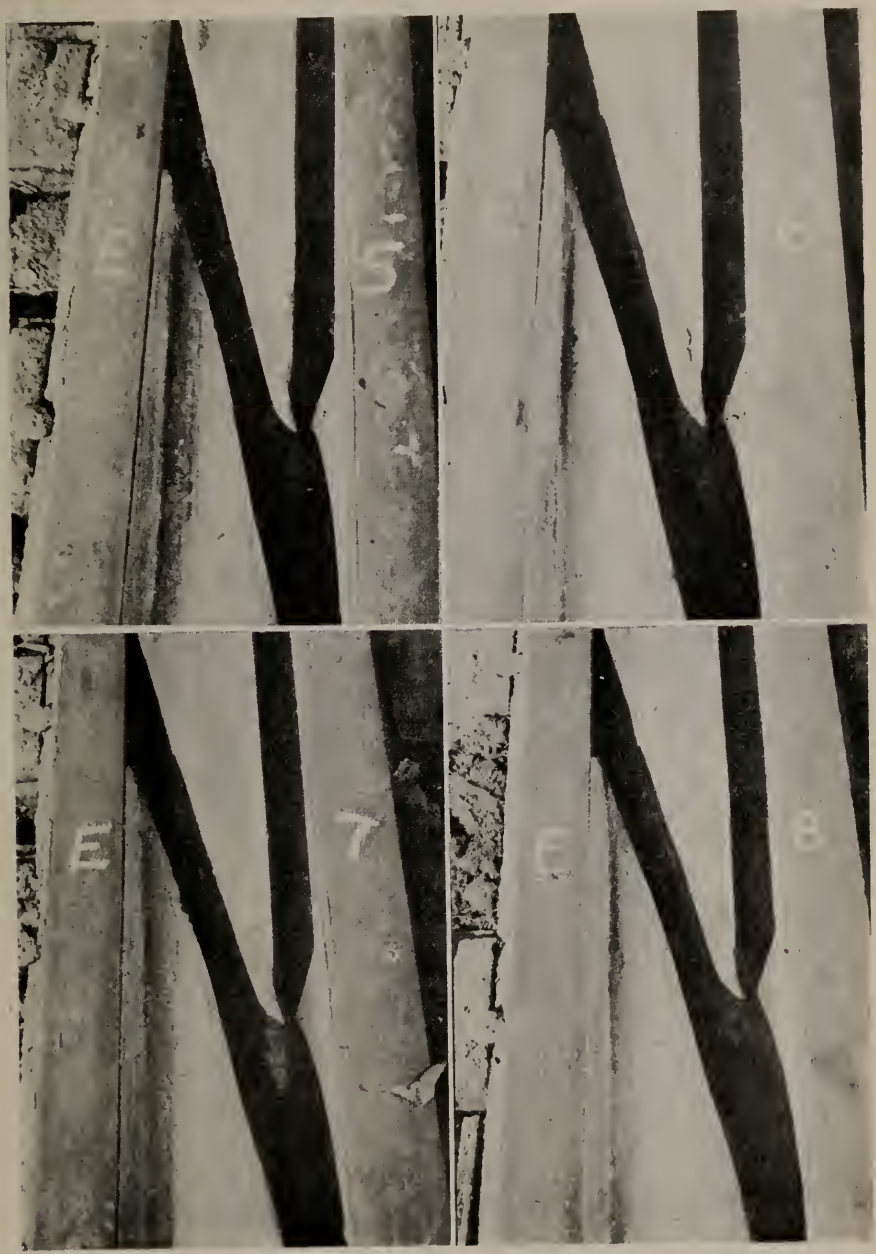


Fig. 4.—Views of Four Test Frogs of East Panel—Mannheim Test Installation—Chicago, Milwaukee, St. Paul & Pacific, Taken November 15, 1945. Not Welded.

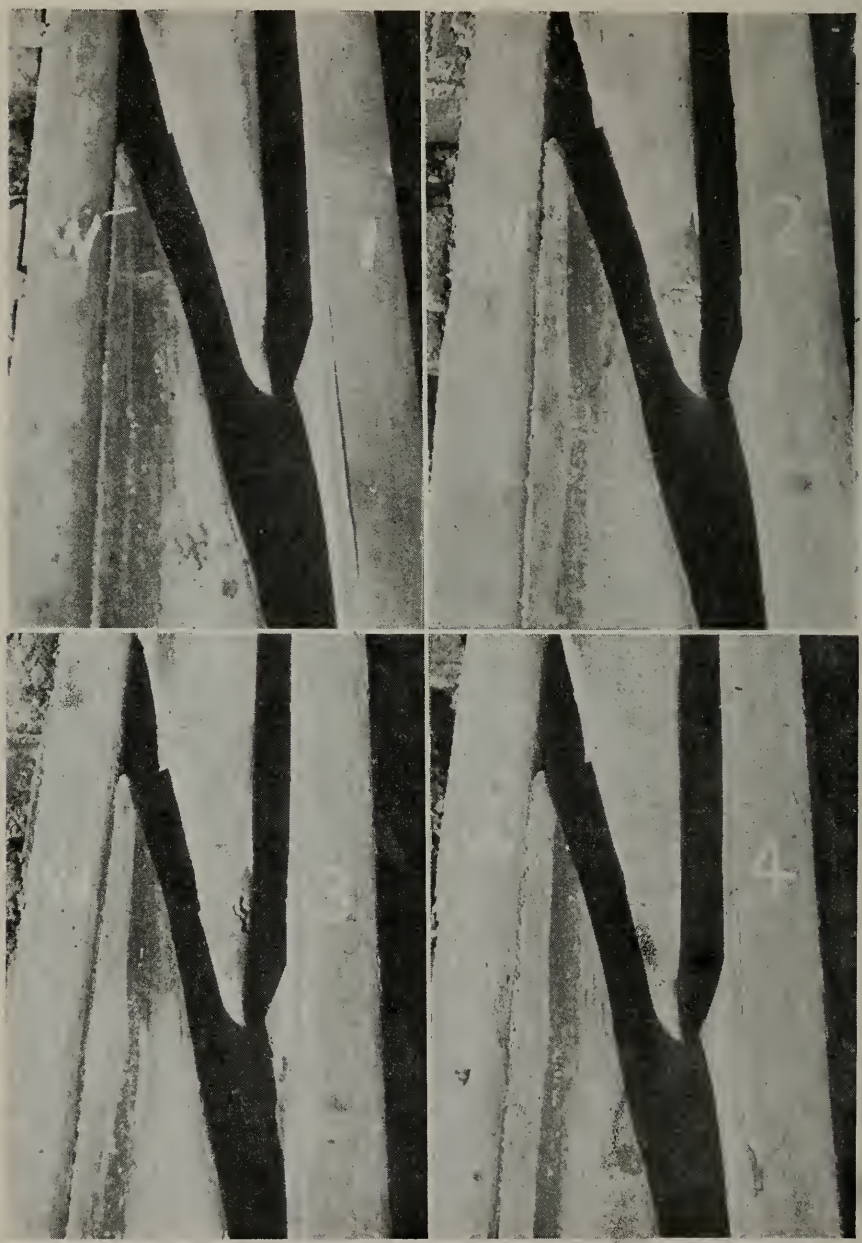


Fig. 5.—Views of Four Test Frogs of West Panel—Mannheim Test Installation—Chicago, Milwaukee, St. Paul & Pacific, Taken November 15, 1945. All rods bare. W–1.—NM rod, 125 amp.; W–2.—CMM rod, 95 amp., cut by torch, point not ground, wing ground; W–3.—NM rod, 100 amp., NM casting; W–4.—CMM rod, 100 amp., NM casting.

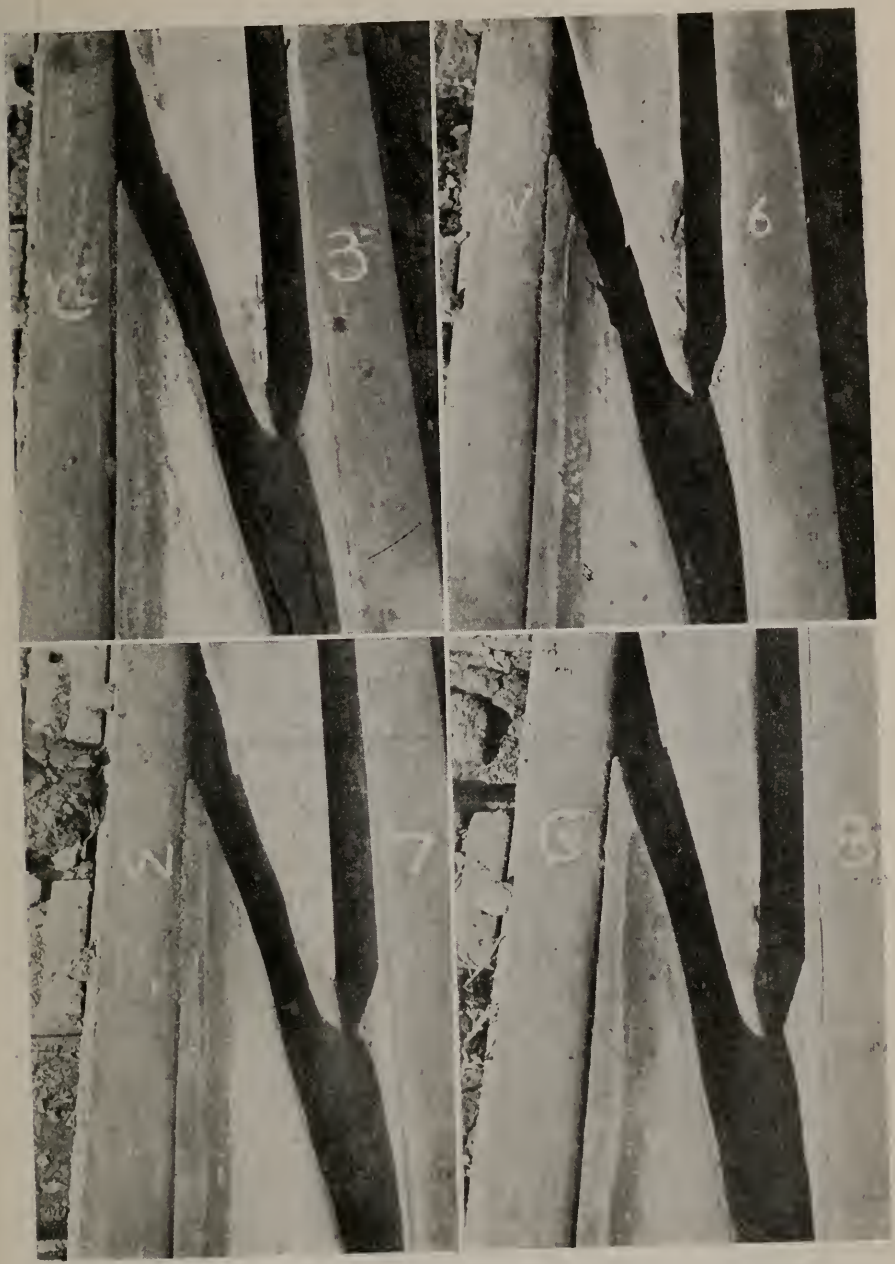


Fig. 6.—Views of Four Test Frogs of West Panel—Mannheim Test Installation—Chicago, Milwaukee, St. Paul & Pacific, Taken November 15, 1945. C–3—NM rod, bare, 75 amp.; W–6.—NMB rod, coated, 145 amp.; W–7.—NM rod, bare, 95 amp., ground ¼-in. depth; C–8—NM rod, 125 amp.

Casting W–3 also had spalling on the point (Fig. 5) and the rate of point batter (Fig. 2) during the past year progressed considerably above normal. The wing was in good condition. This casting was welded with nickel-manganese rod and 100-amp. welding current.

Casting W–4 welded with copper-molybdenum-manganese rod with 100-amp. current was in good condition and the rate of batter was favorable.

Casting C–3 (transposed from the center panel in March 1945) showed slight spalling on the point. This casting was welded with ⅛-in. bare nickel-manganese rod with 75-amp. actual welding current.

Casting W–6 had the point badly spalled and the wing slightly spalled (Fig. 6) the rate of point batter (Fig. 2) increased abruptly during the past year. This casting was welded with coated nickel-manganese rod and 145-amp. welding current.

Casting W–7 was in good condition and showed a normal rate of batter during the past year. This casting was ground about ¼-in. deep before welding and was welded with nickel-manganese bare rod and 95-amp. current.

Casting C–8 (also transposed from the center panel) was in fair condition, a slight spalling being evident on the point. This casting was welded with nickel-manganese bare rod with 125-amp. welding current.

Because of the amount of wear on the fishing surfaces of these special castings and the development of flangeway cracks, it will not be possible to continue these tests and the test castings will be removed.

Résumé of Results

Tentative conclusions were given in last year's report, page 537, regarding the Milwaukee tests. The performance during the past year has not changed these except with respect to "(3) Effect of Use of Cutting Torch." During the past year the point of casting W–3, where the weld was placed directly on the acetylene cut surface, developed spalling. However, the performance was still relatively good compared with most of the other test welds.

Toledo Terminal Tests

To supplement the tests on the Milwaukee Railroad, 11 No. 9 solid manganese turnout frogs which had been installed on the Toledo Terminal Railroad in January 1942 were selected for additional welding tests. These Toledo Terminal frogs all carried the same traffic, approximately 40,000,000 gross tons per year, which produced batter and wear at a relatively rapid rate. These frogs all required welding in November 1943. The welding program was arranged to determine the effect of peening, pregrinding and the amount of welding current (Proceedings, 1944, Vol. 45, page 354). Five of the frogs were welded with bare nickel-manganese rod; five, with bare copper-molybdenum-manganese rod; and one, with coated copper-molybdenum-manganese rod.

This test has been continued and whenever any of these 11 frogs required rewelding exactly the same rod and technique were used as for the November 1943 original welding. Table I gives a statement of the rewelding for each of the frogs up to November 1, 1945.

It will be noted from this table that the weld life has been greater on the facing point than on the trailing point frogs. It is believed this is due to the wing being too high relative to the point, as discussed in last year's report (Vol. 46, page 546), and it is proposed in making future welds to apply the slope-of-wing riser and depressed point suggested in Fig. 15 of that report. This revised contour was applied to Frog No. 11 in December 1944 and was found to give a much smoother riding frog as determined by observation of passing wheels.

TABLE I

Record of Welding of Toledo Terminal Tests Frogs

Frog No.	Location		Welding Conditions: Rod	Current (amps)	Peening	Pregrinding	Date Welded	Date Rewelded
7	Ohio Public Service	(Trailing)	CMM	150	Yes	Surface cleaned	11- 9-43	11-30-44 (8#); 8-20-45 (13#)
8	Starr Crossover	(Trailing)	CMM	90	Yes	Surface cleaned	11-10-43	11-30-44 (8#); 10-21-45 (8#)
6	Hixon - Peterson	(Trailing)	CMM	125	Yes	Surface cleaned	11-10-43	12- 1-44 (7#); 8-18-45 (13#)
10	Consaul Crossover	(Facing)	CMM	150	Yes	$\frac{1}{4}$ in. Deep	11-11-43	11-29-44 (7#).
9	Consaul Storage	(Facing)	CMM	150	No	Surface cleaned	11-11-43	11-29-44 (7#).
2	Cotterel Coal	(Trailing)	NM	150	Yes	Surface cleaned	11-13-43	11-28-44 (8#); 3-17-45 (7#)
4	Sun Oil	(Trailing)	NM	90	Yes	Surface cleaned	11-12-43	5-10-44 (5#); 12-16-44 (6#); 8- 3-45(11#).
1	Woodville Town	(Trailing)	NM	125	Yes	Surface cleaned	11-13-43	12-20-44 (14#); 5-26-45 (14#)
3	Woodville Crossover	(Facing)	NM	150	Yes	$\frac{1}{4}$ in. Deep	11-16-43	12-18-44 (7#).
5	Herbauer	(Facing)	NM	150	No	Surface cleaned	11-12-43	12- 1-44 (6#).
11	Vickers Crossover	(Trailing)	CMM (contcd)	150	Yes	Surface cleaned	11-16-43	12-20-44 (6#)

The copper-molybdenum-manganese type rod has given a somewhat longer weld life than the nickel-manganese type in the test to date. Frog 4 has shown a very poor performance with the low welding current. Otherwise the amount of welding current, peening, or pregrinding has shown no significant effect on the weld life.

General Conclusions

The results obtained on the Milwaukee and Toledo Terminal Railroad tests during the past year do not change the tentative conclusions given on page 567 of last year's report. The Toledo Terminal Railroad test will be continued and additional test frogs have been added to the original eleven in order to obtain more data pertaining to the welding technique.

Report on Assignment 8

Effect of Lubrication in Preventing Frozen Rail Joints

C. W. Breed (chairman, subcommittee), J. C. Aker, W. S. Boyce, E. J. Brown, M. D. Carothers, E. D. Cowlin, M. H. Dick, C. T. Jackson, J. deN. Macomb, G. M. Magee, E. E. Martin, F. H. Masters, R. W. Mauer, O. C. Rehfuss, C. J. Rist.

This is a progress report, submitted as information.

Previous tests have indicated, by the process of elimination, that corrosion of joint bars and rail ends is probably a major factor in reducing the service life of joint bars and rail. Also, corrosion is probably the prime factor in causing joint bars and rail ends to become "cemented" together to form the so-called frozen joint.

Because of the importance of effective joint lubrication, it was decided to install a comprehensive track test installation with different types of lubricants to obtain definite information regarding their respective service performance. Results of laboratory tests with a specially designed rail joint slippage machine (to be described in next year's

report) were used as a guide in selecting the type of lubricants to be used in the field tests. The field tests are expected to determine to what extent the various lubricants will reduce the rate of fishing surface wear, thus prolonging the life of rail and joint bars, and promote uniform joint expansion, thus minimizing the occurrence of frozen joints.

Desired Test Conditions

Irregularity of the action of the lubricants when used with several new joints was manifested by the variability of the results obtained with the joint slippage machine in the laboratory. To secure representative results it was therefore obvious that quite a number of joints must be included in each test section and it was considered that ½ mile of rail or 68 joints would be sufficient for each different lubricant. Also, it was desired to make tests with both headfree and head contact bars. Accordingly, for the number of lubricants to be tested a test section of track five miles in length was required.

It was considered important to have all operating conditions as nearly the same as possible throughout this five-mile stretch of track. The track should be straight where high speed operation over the entire test section would be uniform, without having excessive braking of trains. Turnouts, railroad grade crossings and long bridges (where the rail is ordinarily not anchored) were to be avoided as these are known to affect to some extent rail creepage or the distribution of the rail expansion.

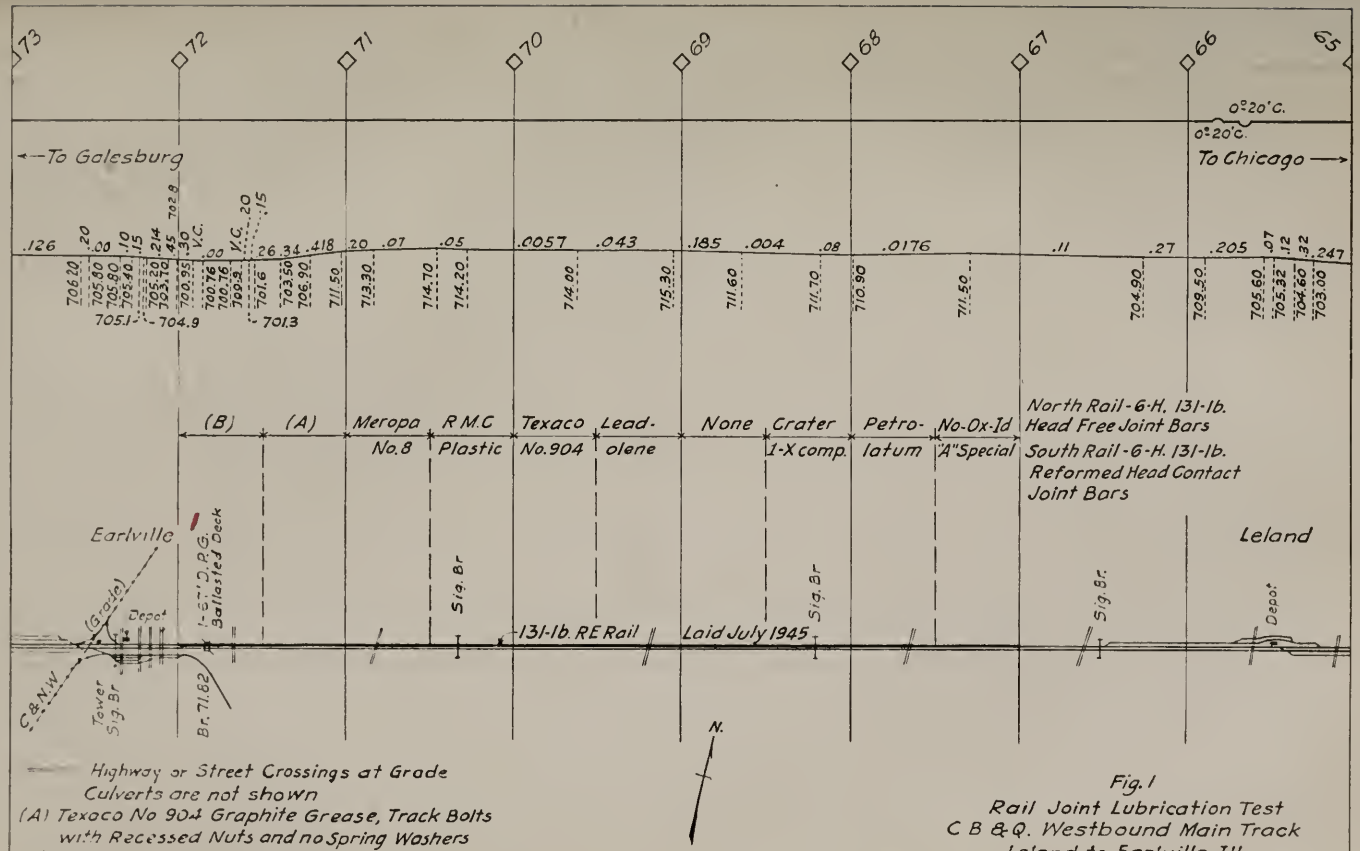
Test Location

The engineering officers of the Burlington Railroad suggested a location ideally suited for the test and agreed to make the installation of the lubricants at the time new 131-lb. RE rail was to be laid. The test stretch extends between M.P. 67 and M.P. 72 in the westbound main line east of Earlville, Ill., as shown in the accompanying figure. This stretch of track was laid in July 1945 and the work of renewing the ties and resurfacing with slag ballast was completed December 1, 1945. In the north rail new 6-hole headfree joint bars, 36 in. in length, were used and newly reformed 6-hole head contact joint bars were applied in the south rail. The head contact joint bars were reformed especially for the test as no new ones could be obtained from the steel mills in time for the test installation. The Burlington Railroad's standard 1-in. by 6-in. track bolt was used throughout the test section. These bolts were manufactured in accordance with AREA specifications except that the thread friction was limited to a range of 5–25 lb. at the end of a 24-in. wrench. Other details of the track relay were as follows: 8-in. by 12-in. double shoulder tie plates with beveled rail seat, two rail spikes and two anchor cut spikes per tie plate, Hubbard Super Service spring washers, and 10 Woodings rail anchors per rail length, 8 forward and 2 back up. All anti-creepers were placed square, (one on each rail against the same tie). From each joint in the direction of traffic the anchors in each ½ rail length were placed as follows: Back up anchor next to the third tie and the four forward anchors against the fifth to eighth ties from the joint.

The test track carries approximately 18,000,000 gross tons of traffic per annum and a small proportion of it is eastbound, or against the current of traffic. The maximum operating speeds are: Diesel passenger trains, 90 mph.; steam passenger trains, 80 mph., and freight trains, 60 mph. There is no speed restriction at the railroad crossing in Earlville and very few trains stop at that point or at Leland.

Twenty One-Half Mile Test Sections of Rail

These sections were arranged as shown in the figure, the north rail having headfree joints and the south rail, reformed head contact joint bars. Each section consisted of



Highway or Street Crossings at Grade
Culverts are not shown
(A) Texaco No 904 Graphite Grease, Track Bolts with Recessed Nuts and no Spring Washers
(B) Standard Liquid Asphalt Rail Coating

Fig. 1
Rail Joint Lubrication Test
C B & Q. Westbound Main Track
Leland to Earlville, Ill.

approximately 68 joints. All of the lubricants were applied with three-knot roofing brushes without handles after the rail ends and joint bars were cleaned with wire brushes. Lubricants were applied to the rail fishing surfaces, over the full height of the web and on the bolt threads. Owing to the generous size of the brushes a liberal amount of lubricant was applied. The lubricants were applied to the rail ends by laborers of the rail laying gang under the supervision of H. E. Durham, track engineer, research staff, immediately after the rail was set in place. In the west half of mile 69 where no lubricant was used the rail ends and joint bars were not cleaned. The reformed head contact bars having just arrived from the reforming mill had more quenching oil on them than the headfree bars which had been rolled and unloaded along the track for a longer period. On the east half of mile 72, designated (A) in Fig. 1, track bolts with recessed nuts, but without spring washers, and Texaco No. 904 graphite grease were used. The purpose of this test was to obtain data where spring washers are not used and to determine the value of the recessed nut in maintaining lubrication of the bolt thread. Also, the ¼-in. recess protects two full threads and in subsequent retightening of the bolts until the two turns are used, the thread friction is about as uniform as in the first tightening of the bolts. This will promote uniformity of bolt tension. As a matter of expediency, the recessed nuts were provided by drilling the recess into the same type of nut as was used throughout the remainder of the test.

Test Measurements and Service Reports

In order to judge the uniformity of the joint gap, measurements of all joint gaps will be made twice a year for all joints, once in December and again in July or August. The joint bar pull-in or wear will be measured each summer on all the joints.This will be done by measuring the out to out distance of joint bars with joint calipers on both the top and bottom ribs at each end and at the midsection, or a total of six readings for each joint. Each July or August the bolts are to be retightened and the applied and remaining tension will be measured in 15 joints near the middle of each half-mile test stretch of rail. It was decided to check the tension near the center of each section to minimize the influence of the adjoining sections and to ascertain that there are no important differences in the average bolt tension of the several test sections. All initial measurements were made in July 1945.

Periodically, one or two joints in each of the 20 test stretches will be removed, examined and photographed to indicate the condition of the lubricant and the amount that has disappeared due to weathering or wear.

In addition to the foregoing information, the Burlington Railroad will furnish an annual report showing the number of loose bolts, broken bolts and joints pulled in two, if any; a loose bolt being defined as one that will shake in its hole or that has vibrated out of place. Altogether the test data and service reports should provide sufficient information to judge the relative merits of the several lubricants, if there are any important differences, and to compare the performance of both headfree and head contact bars from a maintenance viewpoint, as well as from the standpoint of research.

Report on Assignment 9

Recommendations on Number and Placing of Anti-Creepers for Various Conditions

E. E. Martin (chairman, subcommittee), L. L. Adams, J. C. Aker, A. L. Bartlett, T. H. Beebe, F. J. Bishop, E. J. Brown, M. D. Carothers, L. W. Deslauriers, J. E. Fanning, H. F. Fifield, J. W. Fulmer, A. B. Hillman, G. M. Magee, J. S. McBride, J. B. Myers, A. E. Perlman, L. H. Roden, M. K. Ruppert, M. J. Zeeman.

This report is offered as information.

Previous reports on this assignment appear in the Proceedings, Vol. 45, 1944, pages 373–376, and Vol. 46, 1945, pages 569–592.

The tests comprise various methods of rail anchoring at two locations on the Chicago, Milwaukee, St. Paul & Pacific Railroad and at one location on the Illinois Central System. Detailed descriptions for each test and location will be found in the earlier reports above mentioned.

The field and office work in connection with this assignment is conducted by the research staff of the Engineering Division of the Association of American Railroads, assisted by the engineering forces on the respective railroads.

The information is based on rail creepage, tie movement, and joint gap openings.

This report deals with information made available from inspections during the past year together with accumulated data from earlier inspections.

It is proposed to continue the measurements during 1946.

Report on Rail Anchorage Tests on Chicago, Milwaukee, St. Paul & Pacific Railroad Near Mauston, Wis.

This installation was placed in the westbound track of the double-track main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad between M.P. 203 and M.P. 212 near Mauston, Wis., the work being completed in September 1943. A detailed description of the track structure, traffic density, and the methods of making the test measurements was given in last year's report (see Proceedings, Vol. 46, 1945, page 571). Briefly, the rail is 131-lb. with four-hole joint bars and 24 ties to the rail length, and the ballast is gravel containing a large proportion of sand.

Discussion of Test Results

Rail Creepage

Fig. 1 shows the total rail creepage that has occurred from September 22, 1943, to August 7, 1945 for each test section, the method of anchorage also being shown in the figure. As noted in the figure, however, it was found necessary to change the type of anchorage from that originally installed for all of the test sections except A, B, H and I. Fig. 2 gives similar information on rail creepage from June 19, 1944, to August 7, 1945. Comments upon the performance of the individual test sections are as follows:

Test Sections A and B

In both of these test sections the anchors were placed by the end-of-rail method, being boxed in on the ties near the receiving rail end on both north and south rails. Ten anchors per rail length were used in test section A and eight anchors in test section B. The arrangement of the anchors is indicated in Figs. 1 and 2. Continued movement of the rail, although not in itself excessive, has increased the amount of skewing of the anchor ties described in last year's report (See Fig. 3, middle view). Measurements show

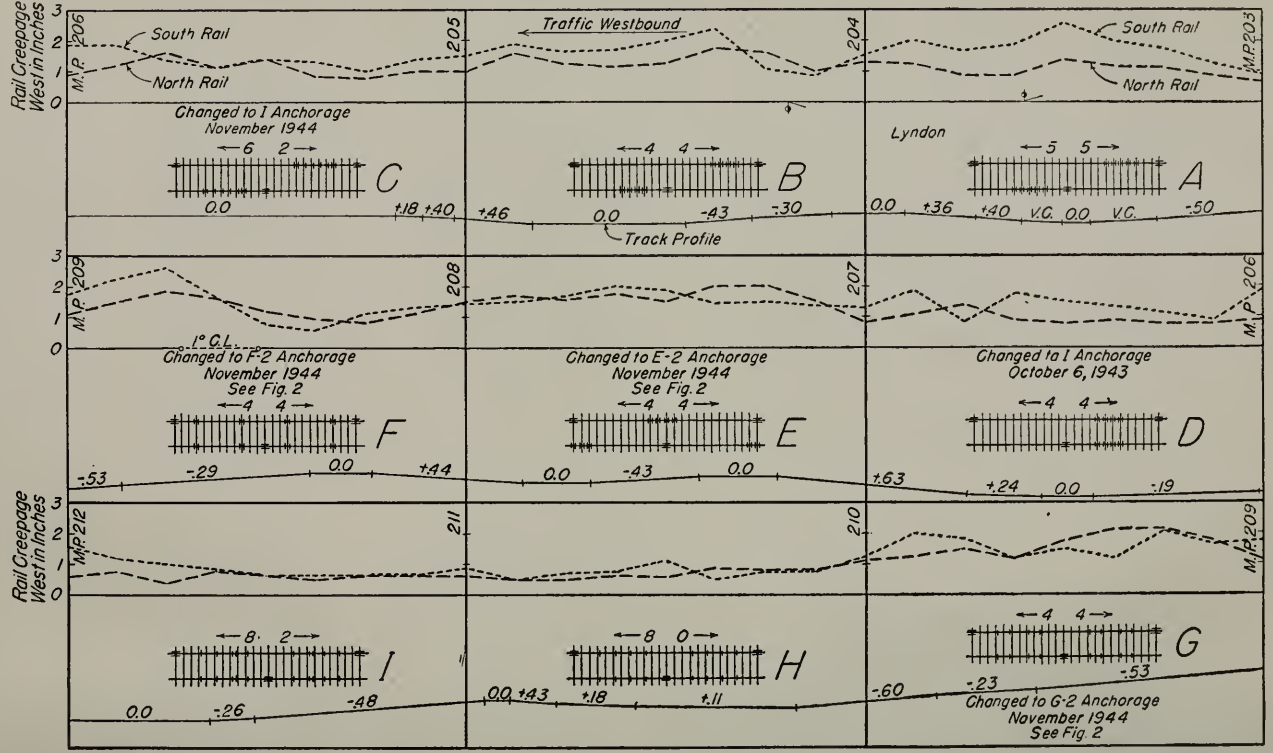


Fig. 1.—Rail Creepage, September 22, 1943 to August 7, 1945, C.M.St.P.&P., Westbound Track, Lyndon to Mauston, Wis.

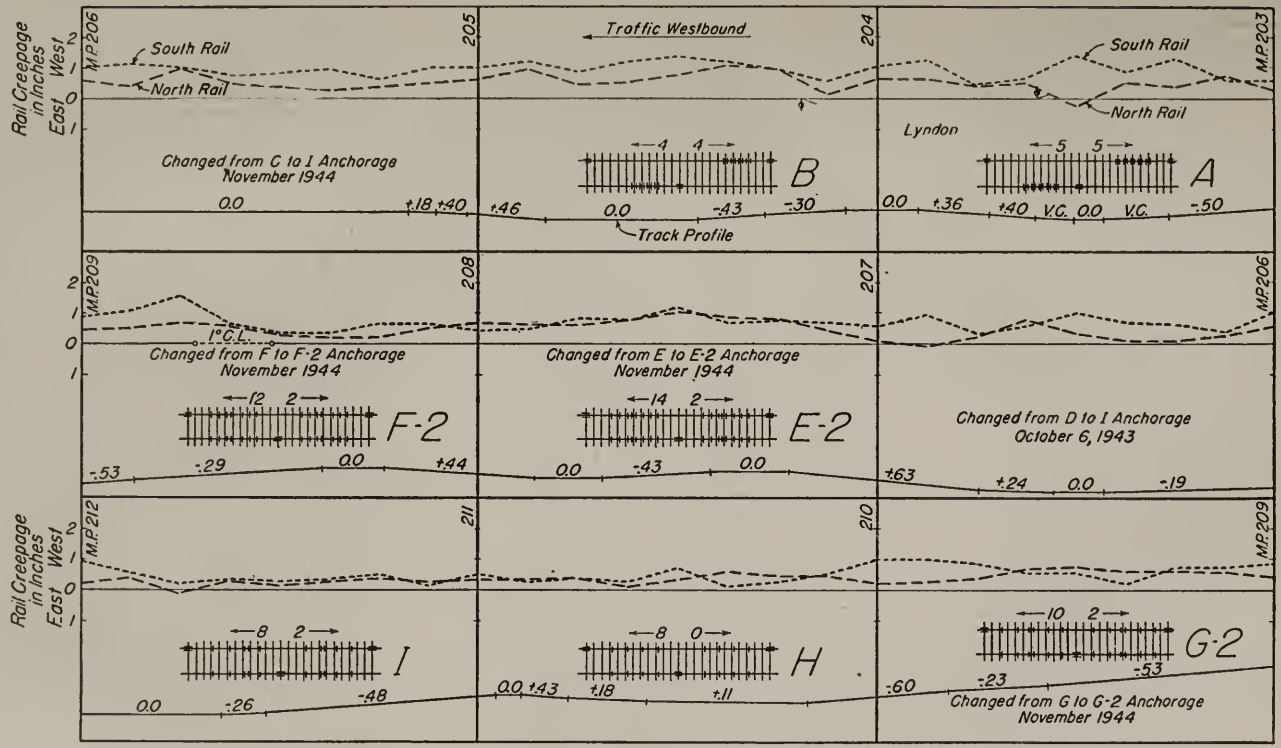


Fig. 2.—Rail Creepage, June 19, 1944 to August 7, 1945, C.M.St.P.&P., Westbound Track, Lyndon to Mauston, Wis.

that the gage has begun to show a slight tightening at the anchor ties with reference to that halfway between (near the joints). As a result, the alinement is becoming unfavorably affected, giving the appearance of the joints being kicked out (Fig. 3, top view). Although this method of anchorage is holding the rail reasonably well, it has shown the attendant disadvantage of skewed ties with narrowed gage and resultant poor alinement of the rail.

Test Section C

This test section was changed over in November 1944 to the Milwaukee standard method of anchorage (section I). The same disadvantage developed with this method of anchorage as with methods A and B; that is, the ties were skewed, the gage narrowed and the alinement unfavorably affected.

Test Section D

As explained in last year's report, this section was changed to method I shortly after the tests were installed. The amount of anchorage afforded was inadequate, permitting excessive rail creepage, and the four anchored ties in each track panel were moved ahead in the ballast, causing the ballast to push up in the crib immediately ahead and drop in the widened crib behind, giving the track a very undesirable appearance. The track surface was also unfavorably affected.

Test Section E

This section was discontinued in November 1944, having the same disadvantages as mentioned for methods A, B and C; that is, skewed ties, narrowed gage and unfavorable rail alinement.

Test Sections F and G

Both of these sections were discontinued in November 1944. The four ties anchored to hold the rail against movement in the direction of traffic in both of these methods were inadequate for the purpose. The back-up anchors provided in test section G were entirely away from the ties and were serving no useful purpose.

Test Sections H and I

These test sections have shown the best performance of any of the anchoring methods installed in this test. The only difference between them is the addition of two back-up anchors in method I. The advantage of the back-up anchors is to hold the rail in the event of rail breakage in cold weather on track on which the traffic is never reversed, or to hold the rail against occasional reverse traffic movements. Where back-up anchors are used, the test results show that they should be boxed in on the ties; otherwise, rail creepage will carry them away from the tie face which they are supposed to contact. In test section I the back-up anchors were about one inch away from the tie face and appeared to have been reset since the test was installed or they would have been farther away. (Fig. 3, bottom view).

Test Sections E–2, F–2 and G–2

When it was decided to discontinue test sections E, F and G they were replaced with method E–2, F–2 and G–2, respectively, as shown in Fig. 2. These methods of anchorage were installed to determine the value of using additional anchors since it was apparent that four anchored ties were entirely inadequate to hold the rail in tests D, F and G, and some rail creepage has occurred with the eight anchored ties in tests H and I. These changes in the methods of anchorage were made in November 1944, and it will not be possible to evaluate their performance satisfactorily until next year's measurements of rail creepage are made.

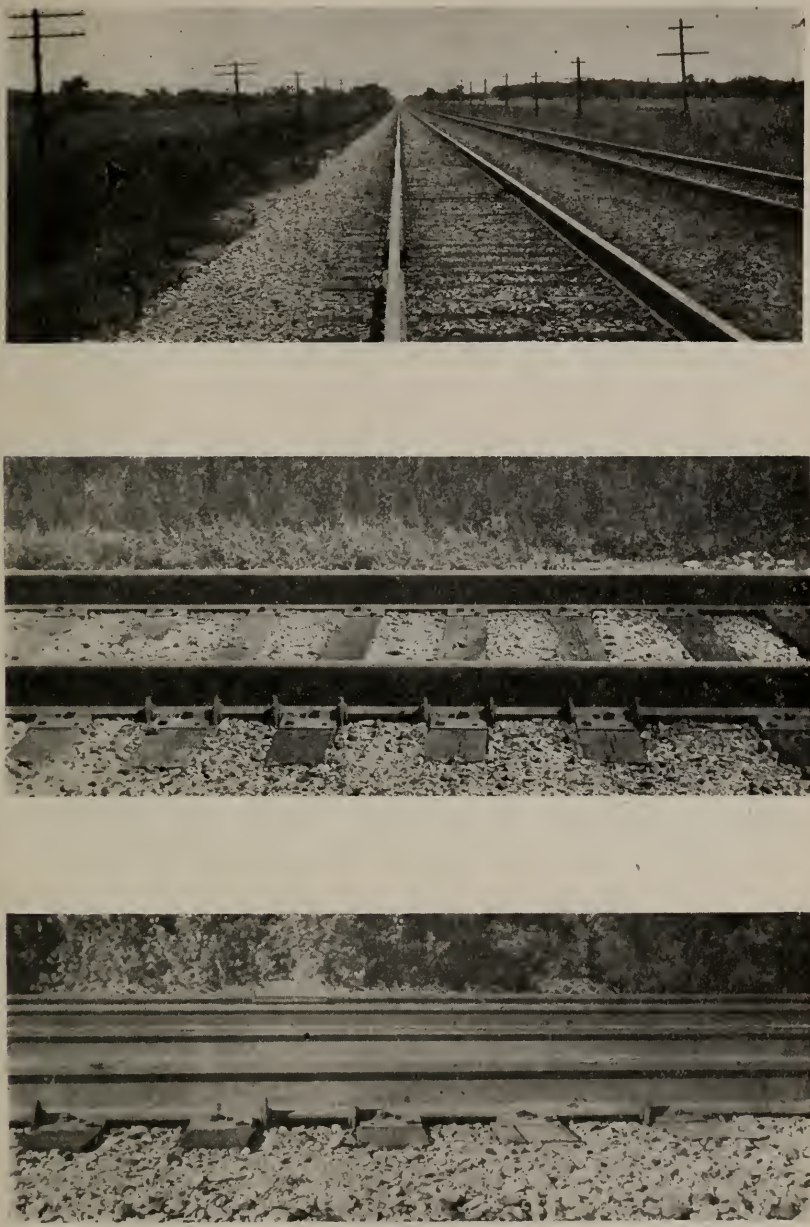


Fig. 3.—Views of Rail Anchor Test C.M.St.P.&P. RR.—Lyndon to Mauston.
Top.—Poor rail alinement with joints "kicked out" as a result of skewed ties with "end of rail" method of anchorage B.
Middle.—Skewed ties with "end of rail" method of anchorage B.
Bottom.—Showing back up anchor away from tie with method of anchorage I.

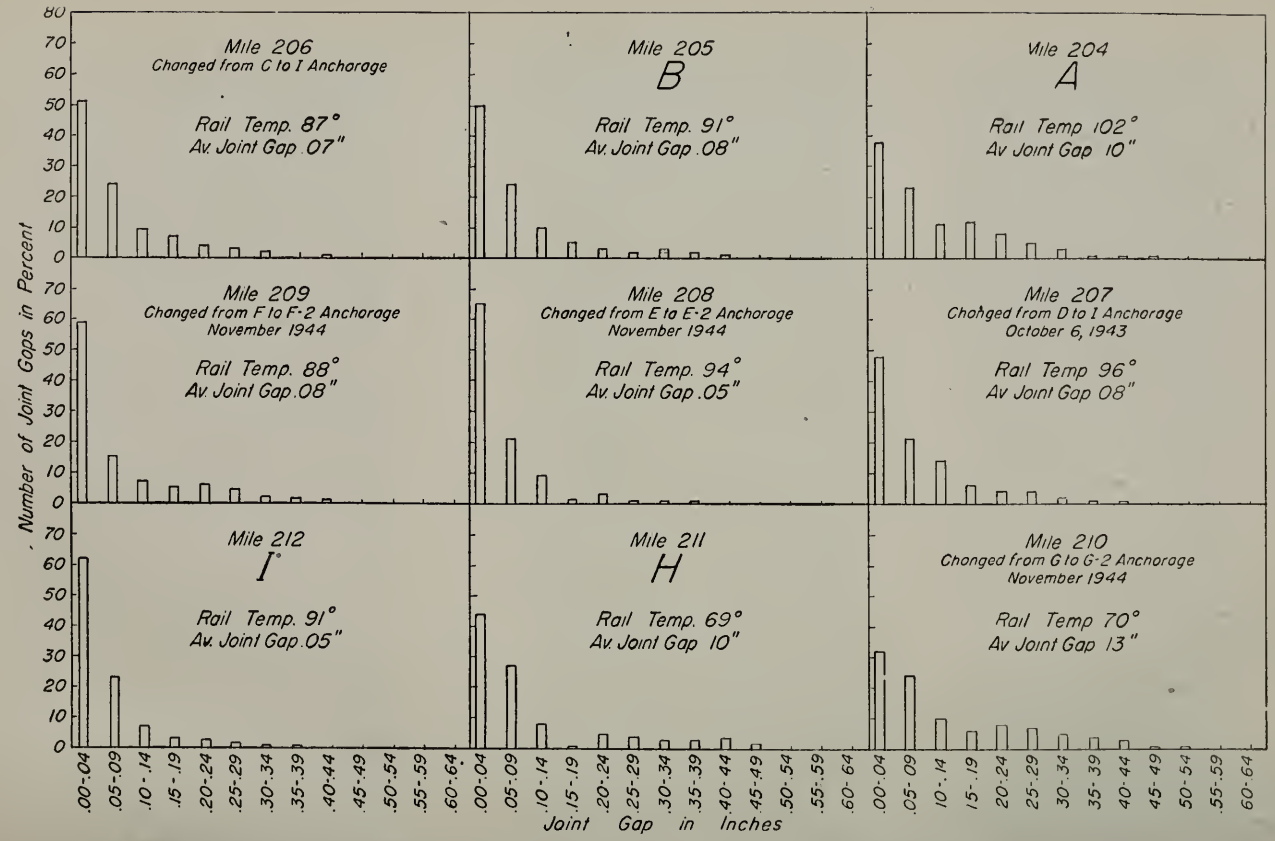


Fig. 4.—Joint Gap on Rail Anchor Test, August 7, 1945, C.M.St.P.&P., Westbound Track, Lyndon to Mauston, Wis.

Joint Gaps

Measurements were made of each joint gap opening on each test section and grouped to show the percentage of the total number of joints found to be within various ranges of joint gap opening, as shown in Fig. 4. In these measurements and similar measurements reported last year, there seems to be no significant difference in the performance of any of these methods insofar as obtaining uniformity of joint gap opening is concerned.

Tie Spacing

Measurements of tie spacing for the ties immediately ahead and behind the anchor ties were made this year by the same method as described in last year's report, except the measurements were made only for test sections B and I, since the performance of test section A is similar to that for test section B and all other test sections had been changed from the method originally installed. The average measurements for the tie

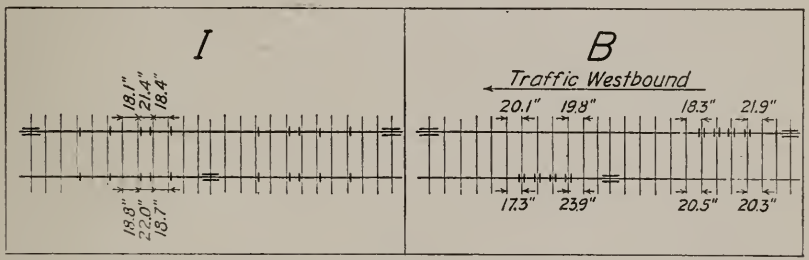


Fig. 5.—Average Tie Spacing, August 7, 1945, Test Sections B & I, C.M.St.P.&P., Westbound Track, Lyndon to Mauston, Wis.

spacing so obtained are shown in Fig. 5. The measurements shown in this figure are the average for all the track panels in ¼ mile of track at the center of the test section. For method B it will be noted that the tie spacing measurements indicate the north rail to have moved westward approximately 1.8 in. and the south rail 3.3 in. This is a somewhat greater movement than is indicated by Fig. 1 and is probably due to the fact that some rail creepage occurred before the measurements shown in Fig. 1 were started. The tie spacing measurements for test section I indicate that both north and south rails have moved approximately 1.5 in. in the direction of traffic, which is also somewhat more than indicated in Fig. 1.

Conclusions

Of the original nine methods of anchorage included in this test, methods H and I have shown superior performance with respect to holding rail against creepage, maintenance of line and gage, and avoiding tie skewing. No conclusions can yet be given with respect to the advantages of an increased number of rail anchors or the number of rail anchors required to prevent rail creepage for the conditions of track and traffic of this test.

Rail Anchorage Test on Illinois Central Railroad Near Kankakee, Ill.

The rail anchorage test on the Illinois Central is also on a track carrying traffic in but one direction but differs from the Milwaukee tests previously described in that large size crushed rock is used for ballast. The test is on the northbound or No. 3 main track of the three-track main line between Kankakee and Manteno, Ill. The rail is 112-lb. RE with four-hole joint bars. A more detailed description of the track structure and traffic characteristics may be found in last year's report.

Discussion of Test Results

Rail Creepage

Measurements to determine the amount of rail creepage and joint gap openings were made in June 1945, with the rail at a moderate temperature. Fig. 6 shows the arrangement of the rail anchorage used in each of the 9 one-mile test sections. The grade line and turnout locations are also indicated on this same figure for ready reference. The amount of rail creepage that occurred from October 26, 1943, shortly after the rail was laid, to June 5, 1945, is shown for the east and west rails separately. In this test installation there have been no changes in the method of anchorage used. The method installed in each test mile has been continued throughout since the original installation. Insofar as the amount of rail creepage is concerned, methods B and C have shown the largest amount of rail movement; methods F, G, H and I have shown the least amount of movement. With one exception the direction of rail creepage has been with traffic. The rail movement for method G was at first against traffic, but it will be noted in Fig. 7, which shows the rail creepage that has occurred during the period October 18, 1944, to June 5, 1945, that in this latter period the creepage movement was in the direction of traffic, as it was with all of the other test sections.

Joint Gaps

The joint gaps were measured at each rail joint throughout the entire nine miles included in the test. For each test mile the measured gaps were grouped according to the amount of joint gap opening and are shown in Fig. 8, expressed as a percentage of the total number of joints in the mile having a specified joint gap opening. No significant differences in the uniformity of joint gap opening for any of the anchorage methods can be observed from this figure. With each method of anchorage an appreciable number of joints were found to be open as much as ¼ in. or more even with rail temperature ranging between 75 and 93 deg.

Tie Movement

Measurements were made at each track panel for ¼ mile of track near the center of each test section to determine the amount of tie movement and skewing. The results so obtained are shown in Fig. 9. For methods B and C where a considerable rail movement has occurred, it will be noted that the tie spacing has been appreciably shortened just ahead of the first anchor tie at the anchored end and lengthened just behind the last anchor tie, particularly on the west rail. The amount of rail movement that has occurred together with the type of anchorage used has resulted in considerable tie skewing for methods B and C, and to a somewhat lesser extent for method A. The amount of tie movement for methods F, G, H and I is quite satisfactory.

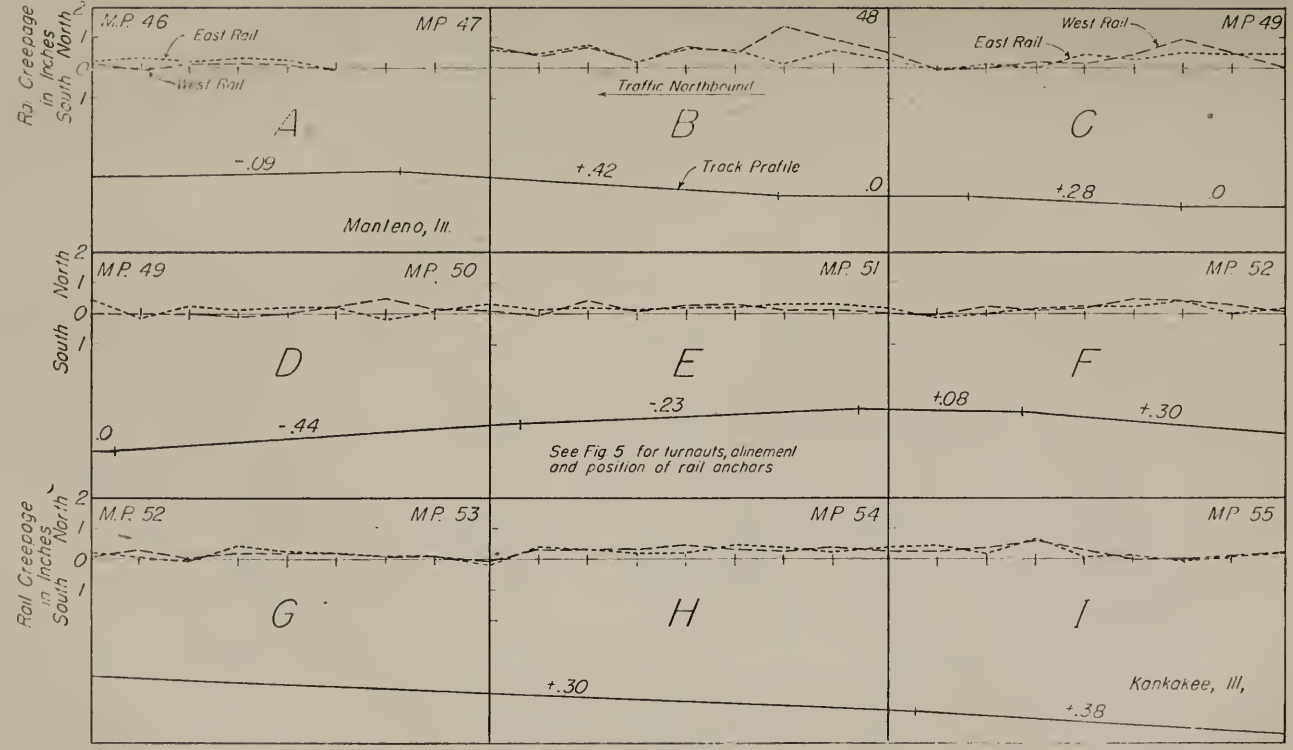


Fig. 6.—Rail Creepage, October 26, 1943 to June 5, 1945, Illinois Central, Northbound Track, Kankakee to Manteno, Ill.

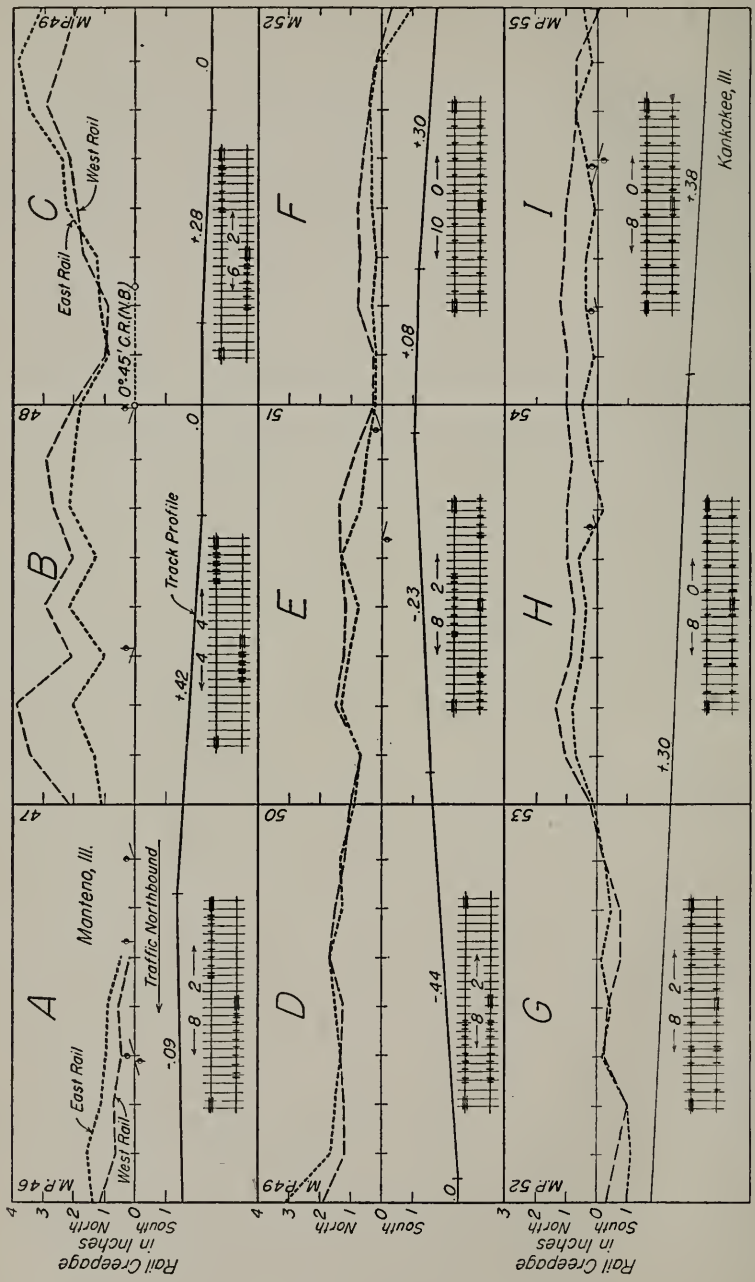


Fig. 7.—Rail Creepage, October 18, 1944 to June 5, 1945, Illinois Central, Northbound Track, Kankakee to Manteno, Ill.

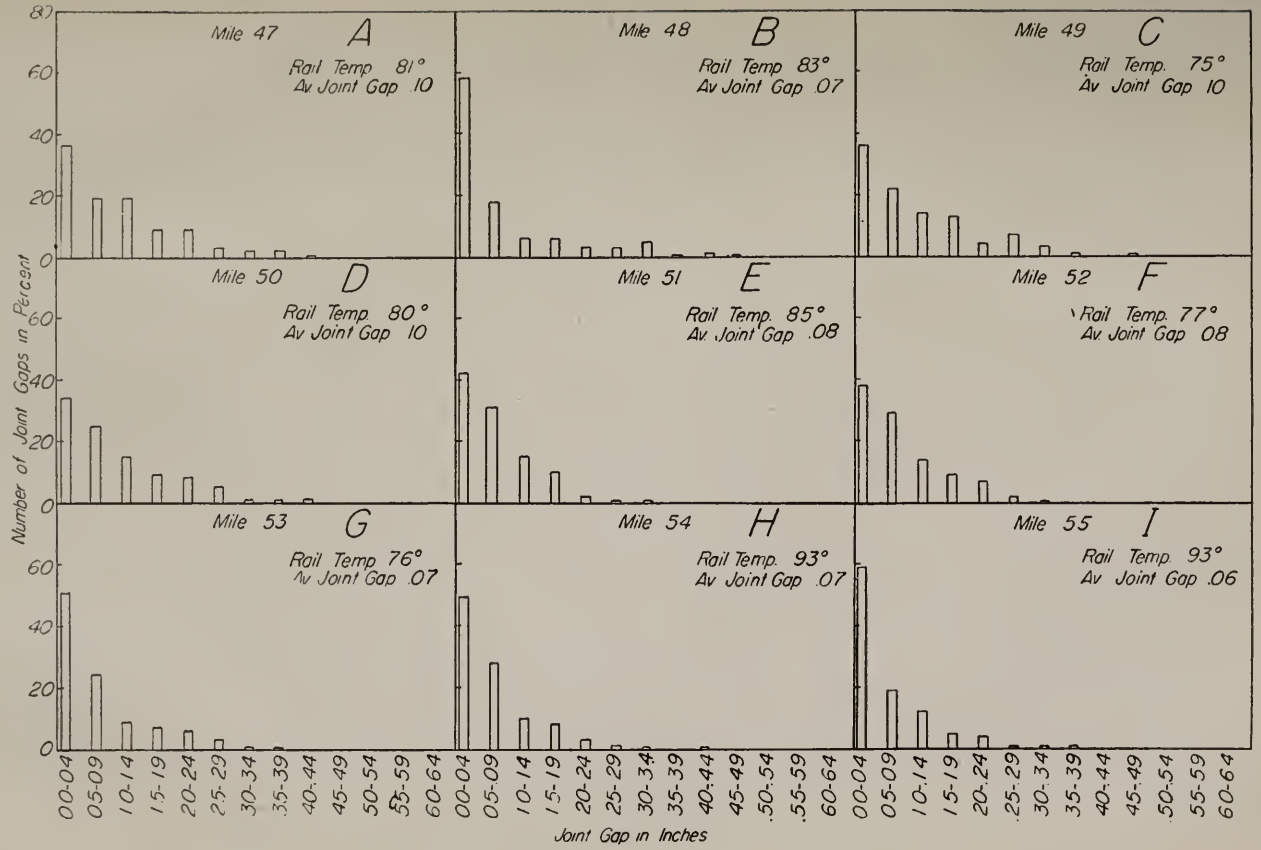


Fig. 8.—Joint Gap on Rail Anchor Tests June 5, 1945, Illinois Central RR., Kankakee to Manteno, Ill.

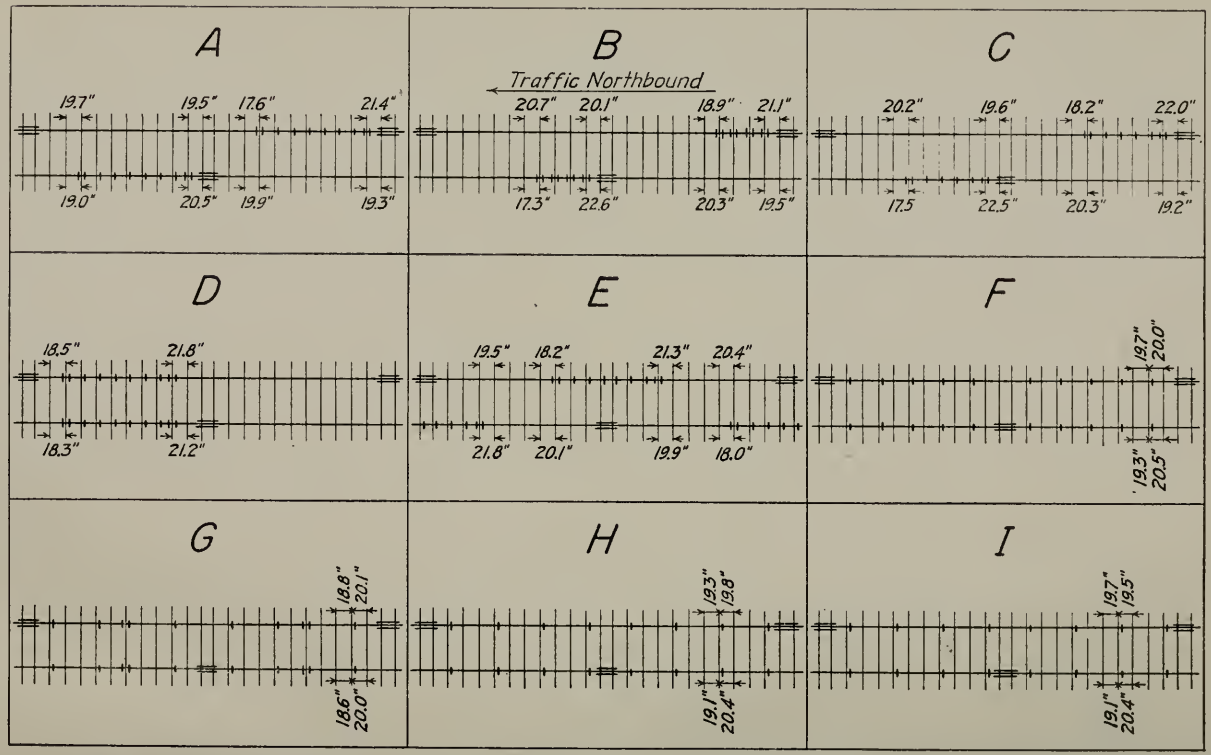


Fig. 9.—Average Tie Spacing, June 5, 1945, Illinois Central, Northbound Track, Kankakee to Manteno, Ill.

Conclusions

Based upon the test measurements to date, anchorage methods B and C have shown the least satisfactory performance, and methods F, G, H and I the most satisfactory.

Rail Anchorage Tests on Chicago, Milwaukee, St. Paul & Pacific Railroad Between Burlington and Kansasville, Wis.

This rail anchorage test installation is in the single track main line of the Milwaukee Railroad between Burlington and Kansasville, Wis. It is the only one of the test installations where traffic operates in both directions over the track. The rail is 112-lb. RE with four-hole joint bars and the ballast is gravel containing a large amount of fine material. A more detailed description of the track structure and traffic characteristics may be found in last year's report.

Discussion of Test Results

Rail Creepage

Fig. 10 shows the type of anchorage that was used in the 9 one-mile test sections. The arrangement is generally similar to that used in the Mauston test with some variations to make the method of anchorage more suitable for single-track operation. The total amount of rail movement that has occurred through each test mile since the tests were installed on November 23, 1943, up to June 14, 1945, is also shown in Fig. 10. The amount of rail movement of test section A and the east half of test section C was so much that these portions of the test were changed over to anchorage method F in November 1944. Fig. 11 shows the rail creepage that has occurred between the last two sets of measurements; that is, from November 16, 1944, to June 14, 1945. Method A, with 6 anchors per rail length, obviously did not have sufficient holding capacity, and this test was discontinued in November 1944. Method B has shown considerable rail movement on the south rail during the test period although the amount of movement during the last period of measurement has not been excessive. Test method C has also shown considerable movement of the south rail, particularly in the east half of the mile. In test method D the amount of movement of the south rail has been considerable and that of the north rail only nominal. In this anchorage method the amount of rail creepage occurring during the last period of measurement has been quite nominal. Methods E and F have shown the best results insofar as holding the rail against creepage is concerned, and for both of these test sections the rail creepage during the last period of measurement has been favorable. Test sections G, H and I have shown considerable rail movement in either one or both rails. During the last period of measurement the amount of rail creepage at G and H was not excessive, but was somewhat less favorable for Section I for the north rail. The rail creepage for the north rail has been consistently eastward. With the method of anchorage used (8 anchors to resist westward movement and 2 to resist eastward movement, not boxed in), a very unsatisfactory condition of anchor-tie contact has developed as shown in Fig. 14, bottom view.

Joint Gaps

Fig. 12 gives the degree of uniformity of joint gap openings, the chart being prepared in the same manner as previously explained. There seem to be no significant differences between any of the anchorage methods with respect to maintaining uniformity of joint gap opening. The measurements were made with rail temperatures between 76 and 106 deg., and a considerable proportion of the joints had joint gap openings in excess of ¼ in. at these temperatures.

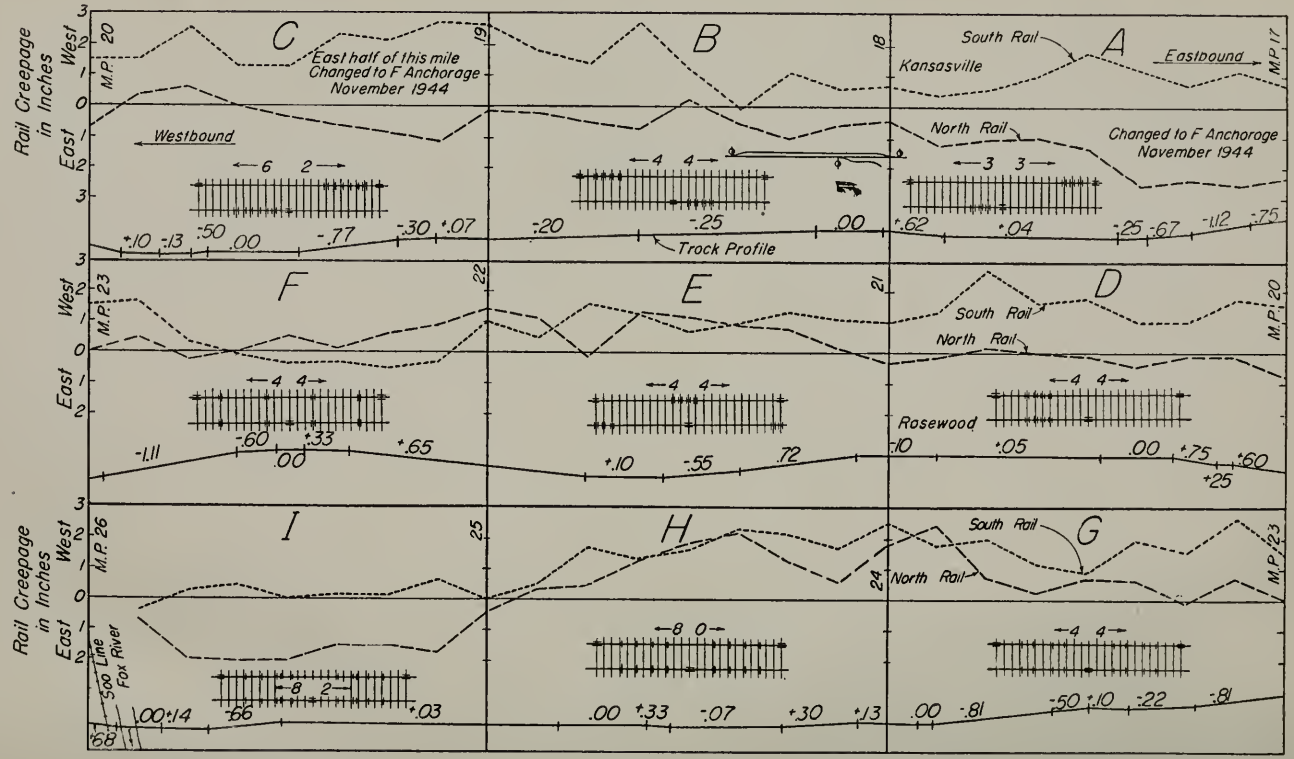


Fig. 10.—Rail Creepage, November 23, 1943 to June 14, 1945, C.M.St.P.&P., Burlington to Kansasville, Wis.

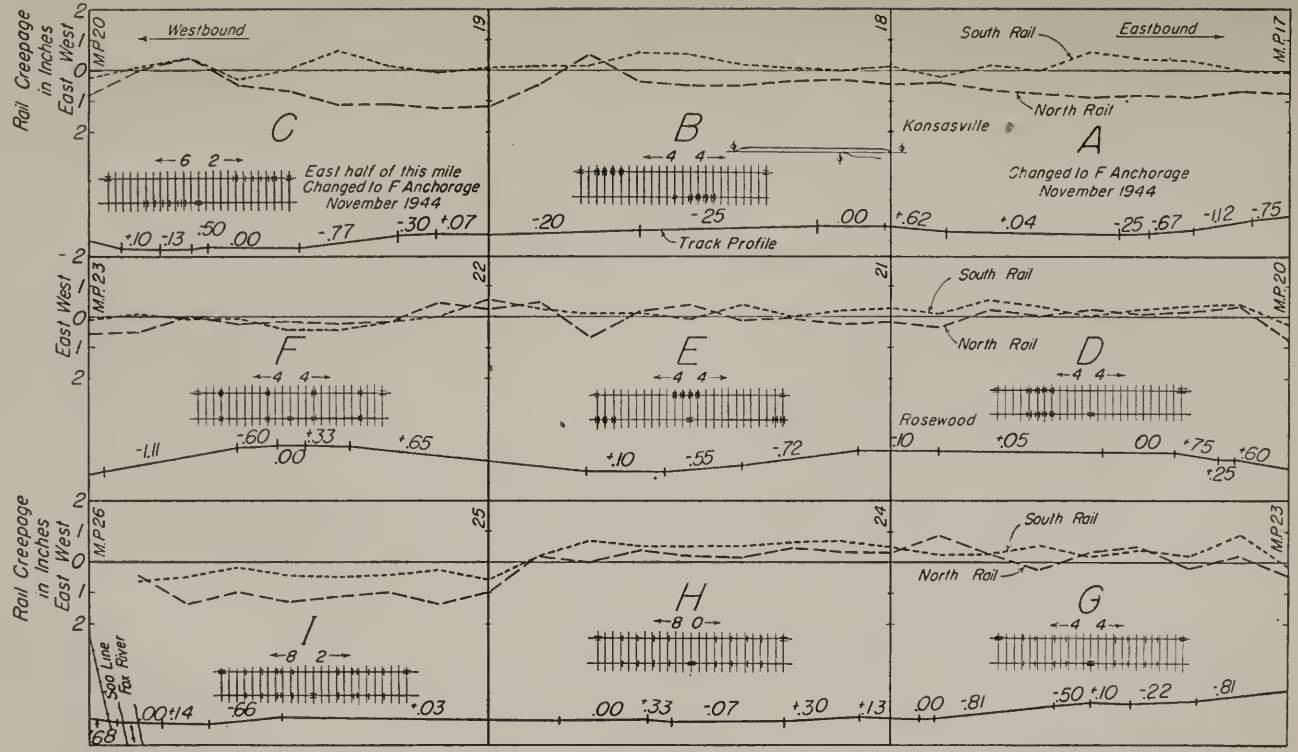


Fig. 11.—Rail Creepage, November 16, 1944 to June 14, 1945, C.M.St.P.&P., Burlington to Kansasville, Wis.

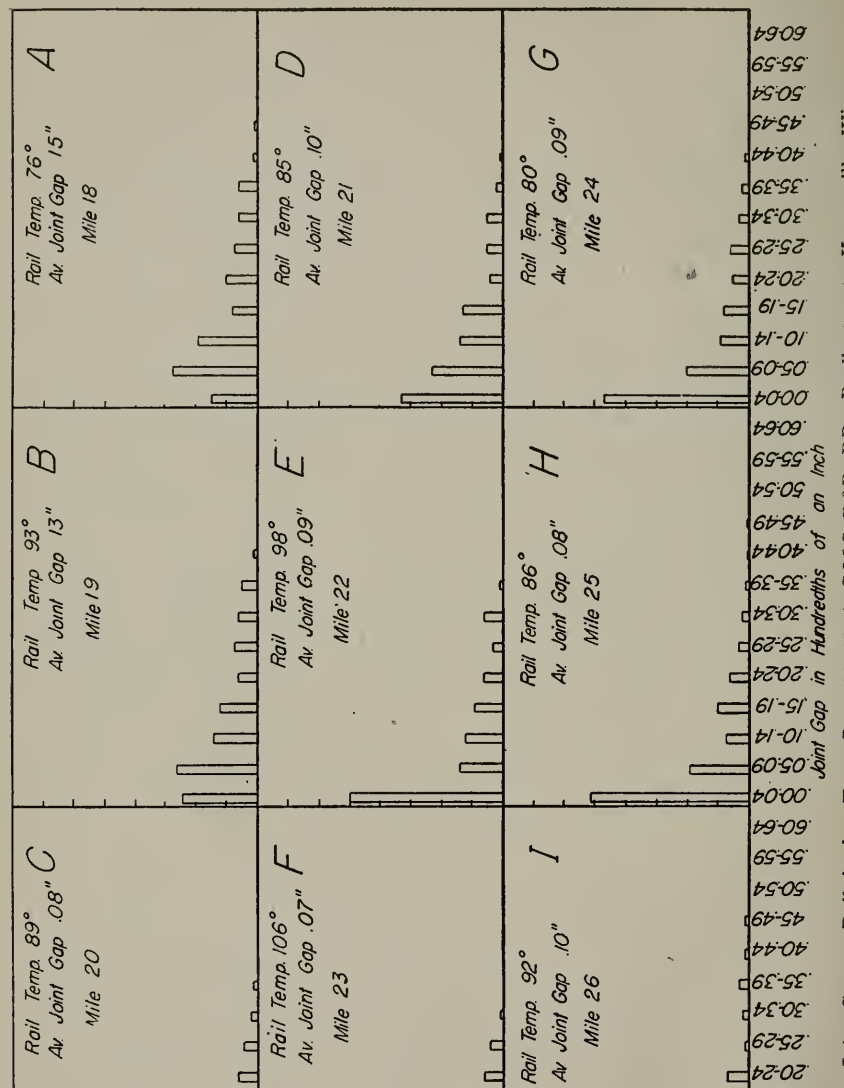


Fig. 12.—Joint Gap on Rail Anchor Tests, June 14, 1945, C.M.St.P.&P. RR., Burlington to Kansasville, Wis.

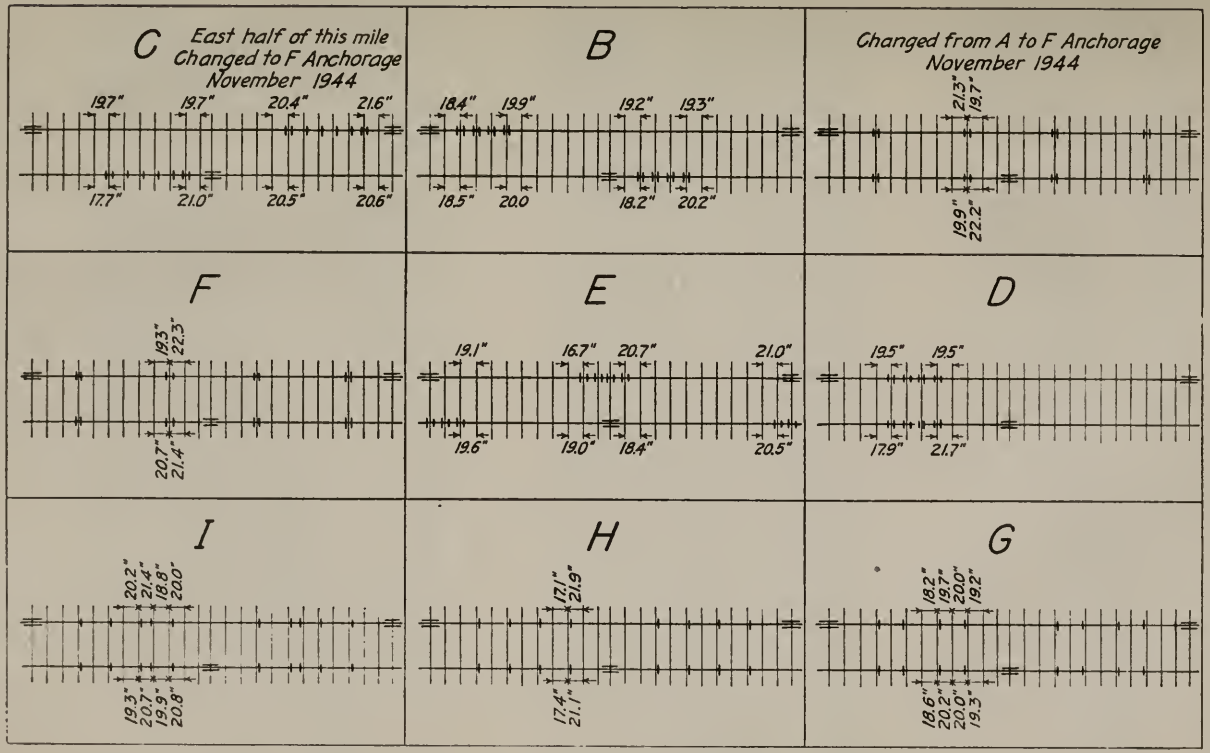


Fig. 13.—Average Tie Spacing, June 14, 1945, C.M.St.P.&P., Burlington to Kansasville, Wis. (Single Track)

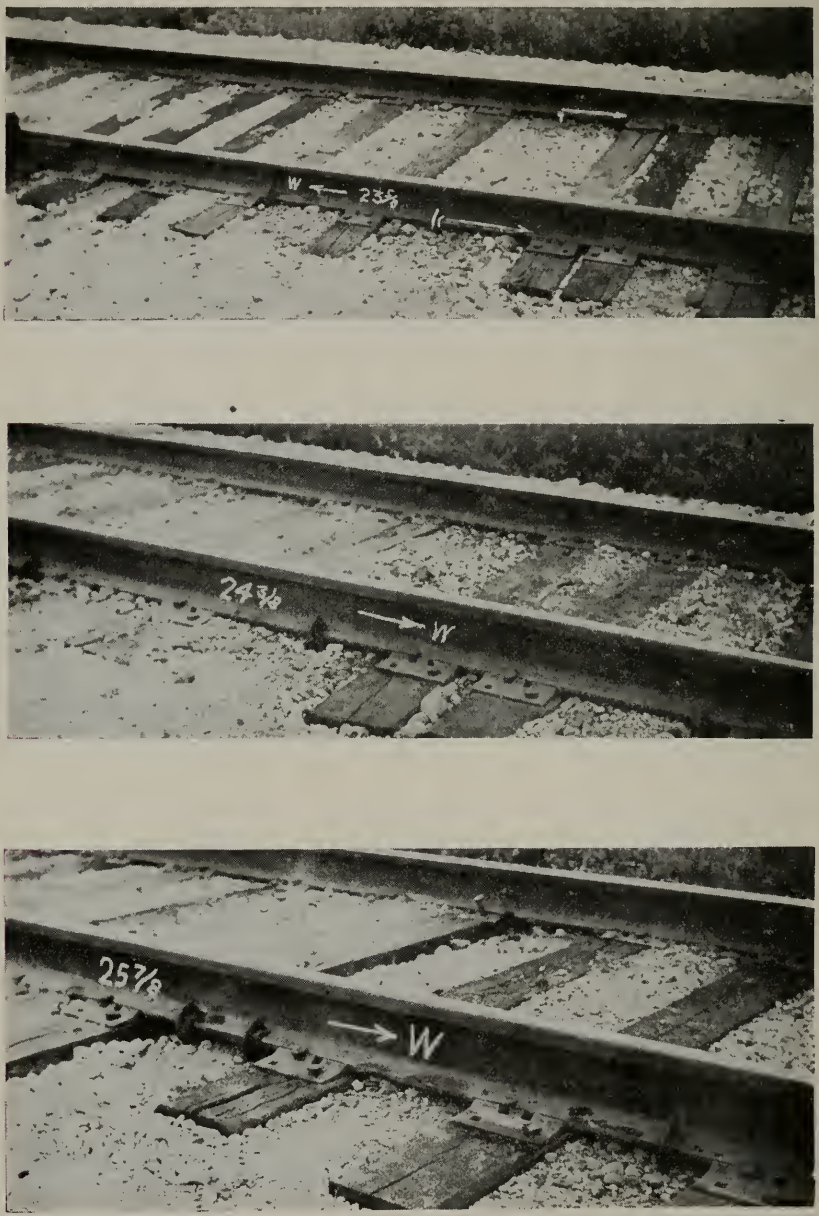


Fig. 14.—Views of Rail Anchor Test C.M.St.P.&P. RR.—Burlington to Kansasville.
Top.—Showing a tie which has been moved excessively by the back and forth rail creepage movement—Method of anchorage G.
Middle.—A similar tie with method of anchorage H.
Bottom.—This condition of anchor position relative to the ties is general over anchorage method I.

Tie Movement

Fig. 13 shows the average tie spacing between the anchored ties and adjoining ties and is useful in indicating the amount of rail creepage and attendant tie skewing that has occurred. The amount of tie skewing in methods B and C is not excessive in this installation. In test method D the relatively greater creepage of the south rail is shown by the narrowing of the tie space west of the anchor ties and widening of tie spacing east of the anchor ties at the south rail. In method E the amount of movement of the anchor ties on the north rail (2 in.) as indicated by the average tie spacing, is somewhat in excess of that indicated by the rail creepage measurements. This is true in test section F, where the tie spacing measurement indicates a rail creepage of the north rail of 1.5 in., whereas the rail creepage measurements throughout the middle portion of the test mile indicate only a small westerly movement of the north rail. The tie movement at test section G has not been excessive throughout the central portion of the test mile. In test section H a rail movement west of approximately 2 in. is indicated, which is in good agreement with the rail creepage measurements. In test section I a considerable eastwardly movement of the north rail, found in the rail creepage measurements, is reflected in the measurements of average tie spacing.

In this test a considerable movement of an occasional tie has continued to occur, as reported last year. (See Fig. 14, top and middle views). These ties may or may not be anchor ties, and they frequently continue to move until they come entirely in contact with the adjoining tie. It has seemed that this tie movement is related in some way with the two-directional traffic, perhaps producing a ratchet-like action within the grip of the tie plate, causing the tie to be moved when the rail moves in one direction, with no tie movement when the rail moves in the opposite direction. The number of moved ties of this nature as found in the various test miles is indicated in the following tabulation:

Anchorage Method	*No. of Moved Ties*
A	64
B	48
C	72
D	14
E	13
F	10
G	64
H	40
I	32

Conclusions

It is quite evident from the performance of the 9 one-mile test sections that the problem of rail anchorage on single track carrying traffic in both directions is considerably different from that on multiple tracks carrying traffic only in one direction. It seems evident that effective anchorage must be applied to the rail to resist rail movement in both directions. Also, it seems desirable to box the anchors on each side of the tie so there will be restraint to rail movement immediately and irrespective of which way the rail tends to move. Of the various methods of anchorage included in this test, method F has shown the most generally satisfactory result. However, the anchorage afforded by this method would be improved by the addition of four more anchors to the rail length, thus providing six to resist movement of the rail in either direction.

PROCEEDINGS

Report of the opening session of the meeting on Tuesday morning, March 12, 1946; the closing session on Thursday, March 14; and other business not related to the presentation of the committee reports

Opening Session, Tuesday Morning, March 12, 1946

The opening session of the forty-fifth annual meeting of the American Railway Engineering Association, held at the Palmer House, Chicago, convened at 9:45 a. m. March 12, 1946, President A. A. Miller, chief engineer maintenance of way and structures, Missouri Pacific Railroad, presiding.

President Miller: The meeting will please come to order. This is the forty-fifth annual meeting of the American Railway Engineering Association. The meeting is also the concurrent session of the Construction and Maintenance Section, Engineering Division, Association of American Railroads.

The first order of business is the reading of the minutes of the last meeting. Because of the desirability to forego the holding of a convention last year, while the requirements of war made that practically necessary and the patriotic thing to do, in lieu of a meeting of the membership, action on committee reports was taken by letter ballot, the result of which was printed in Vol. 46, Proceedings for 1945, a copy of which was furnished to each member.

Unless there is objection, the reading of the result of action on the letter ballot will be dispensed with and the proceedings as printed stand approved. As I hear no objections, the minutes stand approved as printed and sent out.

Address of President Miller

By reason of a custom of long standing, that undoubtedly sprung from an implied obligation in the constitution of the American Railway Engineering Association, I wish to present to you by the way of an accounting of my stewardship some facts and information which might be used for molding our plans anew, since we may well agree that the ever unfolding universe makes influences for our progress when appreciated, creates thoughts and ideas for our legitimate expansion when understood, sustains balance and harmony when righteously realized, and is forever calling upon us to go farther and higher.

These accounts by your presidents during the some forty-seven years since the founding of the American Railway Engineering Association record but briefly the great magnitude of its work, the excellence of its accomplishments, the growth of its influence, the unselfish efforts of all its members, and their magnificent loyalty to

purposes and principles, the ever unafraid and unswerving vision, the adherence to ideals as well as fundamentals, the intense and always inspiring cooperation, the selfless sharing of benefits whereby, and because of them, your Association has grown greater with the years and now occupies a high place among organizations, associations and institutions which contribute effectively and well to the economic life of our nation and the welfare of our railroads.

As the pages in the record of the work and accomplishments of your Association covering nearly half a century are turned and we ponder the substance therein, there comes to us an inspiration, and the renewing of the spirit to grow stronger, go higher, proceed farther,—for the record of yesteryear and yesterday has in it much of the sturdiness of the pioneer; it challenges us to make of our today the sometime "Inspiring yesterday and yesteryear."

In those pages are recorded anxieties as well as victories, adversities but no failures, the influences of wars as well as the benefits of peace, the joys of overcoming as well as the experience of gloom as when some cloud darkens the sun that it can not forever conceal.

We record today the passing of a great conflict—known as World War II—a struggle in which the souls of men have been sorely tried as most of us well know—and for many of us the trial has been almost beyond human endurance. It would be indeed strange if both the immediate and also the far reaching influences of such a terrible mental, physical and material upheaval did not presently and adversely affect in some measure the institutions, associations and organizations of men.

Your Association has been affected by the great conflict, but there are no places weakened that can not be strengthened; no procedure slackened that can not be restored; no progress retarded that can not be accelerated. Nothing of the real life, substance, purpose or inspiration of your Association has been shattered nor is in need of major repairs.

As we take note of and record some of the experiences, accomplishments, and procedures of the year just past, we may find it profitable to focus our minds' camera on the future and develop the picture and the plans which best promote the influence, strength and welfare of your Association, which in turn would be reflected in benefits to our railroads in particular—the greatest instrument of defense for our nation—and to our people as a whole.

In order that there may be a clearer understanding of some of the matters which I propose to bring to attention, I will review briefly some of the more tangible evidences of the state of your Association; some important and vital parts of which are covered more in detail in the reports of the secretary and the treasurer.

Membership

Membership in the Association has increased during the last year at a more rapid rate than in any other recent year. There are several reasons why this has taken place. It is a fact, borne out by records, that the membership in the Association generally rises during periods of large railway earnings, which usually synchronize closely with greater production and larger earnings in other industries. There are at such times a greater number of applications for admission to membership in the Association and a lesser number of resignations and delinquencies, and generally the reverse is true when the trend of earnings is definitely downward. These are some of the results coming out of the influences of economic changes which are not peculiar to your Association but obtain in all kinds of organizations and activities that depend upon the economic wel-

fare of our nation for much of their strength, expansion and progress. Firmness of purpose, determination to progress and an inspired desire to expand are retarding influences to effects when adverse conditions and situations arise and obtain; and when adversity is overcome, they also strongly serve to accelerate the work of building the structure, which is clearly seen in the purposes expressed in our Constitution and visualized by the founding fathers of our Association.

There came to our country during the year 1945 a total of 1090 Chinese technicians and of this number 225 were placed with 31 different railroads throughout the United States for one year's training. These men, some of whom are attending the convention, are exceptionally well qualified engineers who are very anxious to obtain the most and best that they can in a limited time respecting how and why we construct, maintain and operate railroads as we do in the United States. It was wise and also quite natural that some of these men should seek membership in the American Railway Engineering Association to supplement and intensify their training; this they did and our membership includes a number of them. We welcome them and expect that they will be goodwill ambassadors when they return to their native land.

While it is true that membership in the Association has increased during the last year, due to some extent to such favorable and probably nonrecurring influences as just cited, yet it may be stated with satisfaction and assurance in respect to our membership that we continue to remain strong in numbers, influence and substance; and we can expect with confidence that any and all progress and expansion in the cultural, educational and economic life of our nation in the future will be reflected in your Association in a measure heaped high and packed down.

Finances

The financial statement of your Association shows that in the past year there was an excess of revenues over expenditures to the extent of $2,936.33. We find here the influence of the high level of railway earnings reflected, and also the augmented demand for our publications resulting from the war. Because of the limitations imposed on rigid budgetary control in an institution like the American Railway Engineering Association, it is necessary to take a long range viewpoint of the Association's finances. Expenditures vary from year to year because of marked differences in the outlay for publications. Periodic reprintings of the Manual and the Trackwork Plans result in occasional marked increases in the annual expenditures. It was rather expected that a situation of this kind would be presented during 1945, but because of the desirability of postponing the reprinting of the Manual until some rather extensive revisions could be worked out, it is now expected to reprint the Manual during the present year. Consequently, we must anticipate that the expenditures during 1946 may be somewhat greater than the revenues. It is too early to predict the effects of prospective increases in costs on the finances of the Association; in this respect we are not isolated, for all business is confronted with such unpredictable matters at this time. A very noteworthy observation in this connection I think is the fact that the annual dues assessed the members of the Association remain today at exactly the same level as when the American Railway Engineering Association was organized in 1899.

Thus, we note there has been a healthy increase in the membership, and the finances of the Association are in a sound condition.

There is a sustained demand for our publications and a very gratifying evidence that our Manual of Recommended Practice continues to enjoy the esteem of those who find it useful and necessary in their work; this to some extent, it should be understood, is the concomitant of the war effort.

We find that the reports presented to you this year cover the smallest number of printed pages in a considerable period; and of the pages printed, a highly important part was the work of your research staff; this is significant and important to note for it indicates a trend in the strengthening of the work of our committees through processes foretold by several of your presidents and which are, and will continue to be, an important aid in fabricating the substance in committee work.

There has been a decline in the number of committee members actually participating in the work; and there have been fewer young men identified with the work of the committees, and for obvious reasons few committee meetings were held during the year. But this is not, and should not be, discouraging for "we went to war" and we took into that terrible conflict most all that we had or could give; little did we have left but "The Thunder of Sinai,"—still echoing the Law down through the years, but that was a lot to have left to us, for we possess not much that has more enduring value; even the Mount of Vision lost some of its luster and was dimmed during that terrible time for it lost its "Rainbow" temporarily, because our young men "had gone to war" and they took with them our thoughts, our prayers and our love; those of us remaining behind were worried, anxious, sad, wounded—but determined, tenacious, inspired to carry on to victory. Yes—we carried on as best we could; they carried on with all they had —and how gloriously and magnificently did those who "went away to war" for us fulfill our purposes and complete their task!

We are experiencing, and to some extent suffering from, the cumulative effect of the excessive demands which the war years imposed on the depleted engineering and other forces of the railroads. Except for the time occupied in attending meetings, committee work of the American Railway Engineering Association has always been assumed to be a "plus" service which a man generally performs outside the tour of his regular duty, but during the war railroad men with all others have not had the time to give to the Association what their minds and spirit were prompting; this shou'd be very definitely understood and fully appreciated.

Few Young Men

The Selective Service Act effectively removed from the ranks of the railways substantially all of their young men, while in the years just prior to the war the recruiting of new employes was virtually nonexistent because of the economic situation. It is therefore no exaggeration to say that a sizable part of a full generation of men is missing from the engineering and maintenance departments of the American railroads, and that this condition in some measure is reflected in our membership and the personnel of the committees; here again we are neither isolated nor alone for the effects of World War II are bearing heavily on men and their institutions everywhere.

The decline of traffic to peacetime levels with travel restrictions removed, the return of railway men to their positions in civil life, and the renewed availability of young men for positions in railway service should soon bring about a marked improvement in the conditions that have militated against effective committee work. That however is not enough. With a realization of the shortcomings in our operations and the carrying out of our purposes as the result of unfavorable and very restricting circumstances, we should institute a complete reappraisal of our methods and procedures to make certain and positive that we are proceeding along lines that will produce the most valuable and beneficial results; in fact, we should go even further,—we should re-examine our objectives to make sure that what we are doing and are undertaking leads to those objectives as quickly as possible and when attained manifest the results which were expected.

What I am proposing is by no means an innovation. There is ample precedent for a study of our policies and procedures in the acts of your Board of Direction in earlier years. The results of such a survey might be no more than an intensification of some things for which the ground work has already been laid. For example, as the result of the persuasive efforts of one of your past-presidents, E. M. Hastings, you adopted an amendment to the constitution creating the junior grade of membership. It is no fault of this measure or of those who fosterd it that its effectiveness was temporarily negated by the Selective Service Act. Through the effort of another past-president, Robert H. Ford, your Board of Direction in 1940 restored to an active status the Committee on Cooperative Relations with Universities, which has since been dealing with what I think is conceded to be one of the most vital problems that confront the railroads today. I refer to the urgent need for devloping measures which will attract to the railway industry, and retain in its service a proportionate share of the young men of superior ability to be found in the graduating classes of our universities and engineering schools. Judging from the reports of this committee, the primary task is to convince railroad management of the obvious and fundamental importance of this problem.

Progress Will Be Slow

While I am sure that all will agree that we should endeavor to recruit young men in augmenting the personnel of our committees, we must realize that we cannot expect great improvement in that respect immediately. In the meantime, therefore, we must rely greatly on the industry, knowledge, skill, interest and inspiring efforts of the veterans in our committee work. They will be confronted henceforth with a double responsibility, namely,—to carry on the work of the committees so that the reports will represent the result of mature efforts, and to train young men to take their places. It must be appreciated by all of us—and the work involved deeply pondered—that the structure we are building is just as strong, and no stronger, than the results coming out of committee work. None of the other activities of the American Railway Engineering Association is so highly important as the work of committees. What the committees do is applied for the instruction, for direction, and for the safe use of the railroad industry as well as by other industries in many instances. These industries expect—and have every right to expect—that what is recommended and made available can be used to a good advantage and with attending benefits. Never for a moment should the work in committees be other than strong and purposeful, and protective to those making use of that work.

I referred previously to the matter of the proportion of the committee reports that represent the work of paid research workers. The thought has arisen on occasion—and from time to time—as to whether the matters pertaining to research are outmoding or replacing committee work in the sense that the term has been and is commonly understood. It can not and never will have any such effects; rather will it be a very necessary aid in supplementing and strengthening the work of several of our committees. The thought may have its basis in the belief of some that some of our committees have been and are engaged primarily in research work. Committees frequently sponsor research or apply the results of research to the work assigned to them, but it is not their province actually to engage in research work themselves. Instead, theirs is the task of synthesis, coordination and simplification in applying to their work the results of scientific investigations, statistical data and accumulated practical experience, as the case may be, depending on the nature of the work involved or the problem presented and under consideration.

We have profited greatly by the increasing amount of research work that is being carried on in the interest of some of the assignments given to our committees wherein this type of aid is required. I am convinced that there is opportunity for an expansion of this program as we gain experience in directing these investigations and develop facility in the task of absorbing the results obtained. I am satisfied that there is a very broad field for committee work that represents the cooperative effort of groups of men having a common interest in a problem of vital importance, and I am looking forward to the day when members of our Association will again be afforded the time and opportunity to apply their energies, interests and diverse experience to work of this kind on the same scale as it was intended and was being done in the past before one emergency requirement after another had to be met and something done about it.

As will be observed in the tabulation appearing in the report of the secretary, there has been a progressive increase in the amount of money that the Association of American Railorads has appropriated annually for research work relating to problems of, and work being done by, our committees. The results of this research work are to be found in the reports of several of the committees,—notably, Rail, Track, Impact, and, —this year,—the Committee on Roadway and Ballast, which is submitting the first report on its study of the grouting of railway roadbeds.

A Serious Responsibility

The granting of our request for money for research work is a source of genuine satisfaction, but it also imposes a serious responsibility. It is not enough that these investigations are fruitful of interesting and comprehensive reports setting forth what the tests have disclosed. We must keep constantly before us the real objective of each of these projects, namely, to find for some pressing problem an answer that can be applied in a practical way in the interest of better, safer or cheaper railway transportation. For this reason we must review our efforts frequently to be sure that the progress being made offers definite promise of beneficial results. In some cases it may be necessary to make a fresh start or take on a different approach, and occasionally there may be no valid choice but to admit a failure. Surely this would be far better than to proceed aimlessly in the hope that "something may turn up." A most exacting analysis and critical, continuing review of work within the committees by the chairman and members of committees, alone, insure positive and substantial progress toward objectives. Great work has been done and is being done, but continuing great effort and inspired work must always be strongly foundationed in our thinking and consciousness, for surely we all know that there is not—can not be—excellence without great labor.

While there was no change in the number of committees during the war, changes were made in the names of three committees in an effort to keep abreast of current requirements. The Committee on Water Service, Fire Protection and Sanitation, upon request of that committee, was changed to the Committee on Water Service and Sanitation, since the old name indicated an apparent though actually a nonexistent overlap with the duties of the Fire Protection and Insurance Section, AAR. The special committees on Waterproofing of Railway Structures, and on Impact were converted to regular numbered committees,—the former becoming Committee 29—Waterproofing, in the interest of brevity; while the latter became Committee 30—Impact and Bridge Stresses, with the object of more nearly describing the scope of its work.

With the coming of V-J Day the need for the emergency committees,—created at the suggestion of Vice-President C. H. Buford of the Association of American Railroads, no longer obtained; the committees ceased to function as they served no further useful purpose and they no longer carried any emergency powers. Accordingly they were dis-

banded with the one exception of the Emergency Committee on Roadway and Track problems. This committee was participating with a group representing the American Iron and Steel Institute in simplifying tie plate design practice and this particular committee did not go out of existence until January 22, 1946, when the matter they were working on was formally turned over to the Committee on Track.

The Manual

The American Railway Engineering Association is an authoritative agency in its chosen field; its Manual of Recommended Practice—the fruit of almost half a century of conscientious effort upon the part of many men—is used in many places by many people at home and abroad. It is the "Voice of the Association" heralding its substance, values and fruitage to all the world. The demands for it—entirely because of its value and usefulness—are satisfactory and satisfying evidence of its acceptance as an authoritative element in the fabrication of the economic life—both useful and beautiful—of our railroads and nation. We must guard it well. It is our voice; we must never permit it to become harsh or coarse or hoarse; it must be kept fine by a constant refining. We must be sure that the Manual is kept up to date. It must be kept abreast of the results of our research. It must evidence a knowledge of the current standards of other scientific bodies. It must be free from internal inconsistencies; it must be the sure, penetrating, confident ways and means to objectives.

It is always of highest and most importance to know that what is in the Manual is correct and up to date. The assignment "Revision of the Manual" heads the list for good and sufficient reasons; and some of those reasons have been given. Some committes, by the very nature of the subjects assigned to them, may never produce subject matter for the Manual; others may have little occasion to submit material for adoption; but the acceptance of the results of their work—and so recorded—makes it supremely important that we fully understand and adequately appreciate that the work of the American Railway Engineering Association—no matter how or where recorded and presented—is of such value and importance that it is widely used and appreciated and maximum benefits are expected from it. Briefly stated: So Love the American Railway Engineering Association, its purposes and its work that our efforts and work, springing from loyal and inspired desire, will contribute heavily in maintaining a high standard of excellence.

Let Us Remember

Then too let us remember in our work that there are bonds to be ever enlarged and strengthened; hand clasps to be more firmly gripped; heart beats to be synchronized; songs of the souls made more harmonious and melodious; divine obligations to be met and fulfilled; "hands across the borders;" "hands across the seas"—should be symbolic, in their closer clasping, of a disposition to better understanding that The Golden Rule is paramount to all rules in directing men in their thoughts, acts and affairs.

It must be a source of greatest satisfaction and most profound gratitude to you—as it is to me—to know that during one of the greatest conflicts in the annals of human experience we have carried on so well; whatever has been accomplished during the past year is primarily due to the splendid cooperation of the members and supporters of the Association—their devotion to work and their duties—and their unselfish loyalty to the ideals and purposes of the Association under most trying and adverse conditions.

I wish to express my indebtedness to Secretary Lacher and his staff, and to the Board of Direction and all for the aid and whole-hearted support which has been so generously given me.

In concluding may I bring to mind that the "Great I Am," "The All-Power" moves in mysterious ways His wonders to perform; and often in history has indicated in startlingly miraculous ways that He brings us back to ourselves; our better selves; our real selves, to rededicate ourselves to higher, nobler things.

Not long ago the man of Adam's making was brought to know that he is on the verge of entering a new and better cycle of time; and that the atom man of hope, faith and charity must realize that All Power—ever existent and always available—is coming within his thought, his consciousness and his comprehension *now*.

This is after all a good old world to live in; let us enjoy it as well as endure it.

God bless America,

God bless The American Railway Engineering Association,

God bless all mankind. (Applause)

President Miller: We will now receive the reports* of the secretary and treasurer presented by Mr. W. S. Lacher, secretary of the Association.

Secretary's Statement

Secretary Lacher: Mr. President, ladies and gentlemen: The reports of the secretary and treasurer have already been published in the Year Book. They are essentially statistical in nature, and their primary purpose is to provide an historic record of the affairs of the Association. Further than that, your president has given you a general outline of the affairs of the Association during the past year, so I will confine my brief remarks to comments on a few trends that you may find of some interest.

As President Miller told you, there has been an increase in the membership, which as of February 15 was 2107, or an increase of 103 during the past year, and, as he said, that increase must be ascribed primarily to the high level of railway earnings and the general condition of the country.

In addition to that, 31 of the new members included in the 103 are Chinese railway engineers of marked ability, well qualified for membership. Obviously, when these young men return to China, some of them will find it impossible to continue as members. However, it is our sincere hope that the Association will continue to be of sufficient usefulness to a great many of them so that they will be glad to remain on our membership rolls.

This increase in membership at this time, follows as a distinct parallel to a stepping up of the membership that occurred in 1919–1920 at the close of World War I. Because we retained a large portion of the new members who joined at that time and the further fact that there is nothing in the influences that resulted in the increase of membership during the past year which savors in any way of a *drive* for membership, I am sure that the increase we have enjoyed during the past year, and which is manifested in the continued receipt of a considerable number of applications for membership, is indicative of thoroughly stable conditions.

There is another trend in connection with the membership to which I would like to call your attention, which has a bearing on this postwar increase, such as we had in 1920. In 1941 the report of the secretary contained a little chart showing the additions to membership in each year since the organization of the Association and revealing graphically what a large jump there was in 1920.

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* Reports of secretary and treasurer, p. 772.

At that time I made the prediction that that jump would be reflected in 1944 by a marked increase in the number of life members. I missed that guess by just one year The big jump came in 1945 instead of 1944, with the result that we now have 245 life members compared with 190 last year and 103 ten years ago.

This increase in the life membership roll is a manifestation of the fact that the Association is becoming of age and after a few years more (I can't predict how long it will be) that life membership group will attain what you might call a state of stability and have more or less of a fixed relationship to the total membership.

As your president stated, we showed an excess of receipts over disbursements of a little less than $3000. That is a somewhat lower figure than has prevailed in most years for some time in the past, except in periods of extraordinary expenditure. For example, in the two years, 1935 and 1936, the expenditures exceeded the receipts by a total of $7000, to cover the added expenses due to the conversion of our Manual to the loose-leaf form. We are now confronted with a similar situation. The stock of Manuals has become exhausted, and we have had to resort to another reprinting. Becauses we underestimated the demands for the Manual during 1945 and the further fact that investigation showed that the committees had not been able to complete a considerable number of revisions that were deemed desirable before we resorted to the printing, we had to postpone the printing until this year.

In the meantime we are continuing to have a demand for Manuals, and it has been suggested that there may be members who have retired or are approaching retirement who would be willing to give up their Manuals. If there are some who would like to sell their Manuals, we will be glad to put them in touch with people who would like to buy them.

We are now in the second year of the AREA News. It hasn't changed much either in form or content from the form in which it appeared in August 1944. Much more could be done with it; there is room for improvement. However, we are handicapped in some respects because we have not had as many suggestions as we would like to get from the members. We would like to hear from you about the AREA News. We are not looking for boosts. The chances are the knocks will do us more good.

Your president paid a tribute to the members, especially those on committees who have given so freely of their time to the committee work. I can't close my few remarks without stressing that point. To me it is a remarkable thing that men who have been as busy as the railway engineers of this country should find time to do what has been done to make these committee reports possible.

I also wish to express my appreciation for the work of the secretary's staff. Much of that work is of a routine nature that calls for exacting attention to detail and yet, at the same time, affords opportunity for imagination and initiative. A great many of the tasks imposed could not be done were it not for the fact that somebody on the staff thought of the scheme for getting the work done with less effort than would have been necessary, except for that show of initiative.

To mention but one item—the membership list gave us an unusually heavy job this year. There has been an unbelievable number of changes, the reasons for which at this time are obvious: the men returning from the armed forces and going back into railroad service in new positions, and the increase in the number of retirements.

Now that the Year Book is finished, we are confronted with the fact that, before the ink was dry, there were at least 25 places in listings that were already incorrect, and undoubtedly a great many more of which we have not heard.

In this connection, I bespeak your thoughtfulness and assistance in letting us know of changes, particularly of men returning from the service. These men have a great

many things to think of besides writing to us and telling us they are back. So I wish you would help us in that respect. (Applause)

President Miller: During the past year, as was noted in the Secretary's report, 36 members of our Association, including Past-President Bond and Past Directors B. R. Kulp and J. B. Hunley, as well as many others of revered memory, passed into the great beyond. So far as it is possible for man to know, they probably are doing a loving work on another plane of thought and action in the great unknown.

Let us rise and stand for a moment in silent tribute to their memory.

(Silent tribute to deceased members.)

President Miller: It is always an occasion of note and importance when we have the opportunity to hear and to learn and benefit from one who brings to our thinking information and conclusions based upon a long and seasoned experience and to give to us whatever of mature judgment may aid us in the shaping of our course.

Today we have with us one who is superbly qualified to give to us many and much of the true values, one who has been a member of this Association for 29 years, was for a number of years chief engineer and president of the Kansas City Southern Railway, and at this time is chairman of the Western Association of Railway Executives.

It is a pleasure for me to present Mr. C. E. Johnston. Mr. Johnston! (Applause)

Address of C. E. Johnston

Chairman, Western Association of Railway Executives, Chicago

Mr. President, ladies, members and guests of the American Railway Engineering Association and the National Railway Appliances Association.

It is good to know that once again people can get together to exchange ideas on subjects in which they have a mutual interest, and I appreciate very much the opportunity that has been afforded me to extend to you a cordial welcome to the City of Chicago. Those of us who live here, in this railway hub of the United States, have looked forward to your coming.

You gentlemen who are responsible for the railroad plants which met the severest tests of wartime traffic despite shortages of manpower and despite your inability to get desperately needed materials and supplies, deserve credit and acclaim in far greater measure than you will ever receive. I say to you simply and sincerely—you have done a magnificent job!

It would be nice if I could say to you, with equal sincerity, May you live happy ever after!

But I am obliged to say that you and all of the rest of us in this railroad business have just begun to fight. All of the ingenuity and resourcefulness which you have demonstrated during our years at war must now be directed, without pause, and with equal vigor, to the problems that lie ahead.

I am not for one minute unmindful of, nor do I underestimate, the influence this group commands in the railroad industry as a whole. Neither am I unmindful of, nor underestimating, the tremendous responsibility this group must share in the hectic period of readjustment and greatly intensified competition which we are now entering.

I often wonder just how far we would be advanced in the art and profession of railroad engineering and maintenance had this Association never been organized. The fact that there has been a need for it during the past half century, and that this need

is undiminished at the present time, is attested by the simple fact that you are still in business still facing forward, and that you have run out of neither troubles nor problems.

No better way exists to further these ends—ends which advance the public interest and contribute to better living standards for the American people—than by the free exchange of ideals and views at meetings such as this. I say this notwithstanding the distorted construction some persons are seeking to place on the Sherman Antitrust Act, under which such conferences as this would be of questionable legality. If there *were* a better way to accomplish these purposes, it surely would have been discovered in the fifty years your Association has been in existence.

Railroad Transportation Is Not Old

As years go, American railroad transportation is not an old industry. Steam railroads came into the American picture about 1830. It was not until about 1837 that the enthusiasm for canals, turnpikes and toll bridges waned and it became clearly recognized that the future of the United States was closely linked to railroad transportation.

Railroad maps of the United States, so far as I know, date back to 1830, when there were a few short lines in South Carolina, Maryland, New York and Massachusetts. All of these, I believe, were equipped with horsedrawn vehicles—buggies for passengers, and wagons for freight. The first steam engine was shipped over from England about 1829.

In 1850, we had approximately 9000 miles of railroad in these United States, made up principally of short lines, and scattered throughout all the states east of the Mississippi river. By 1860, the total mileage had increased to 30,000 miles and had pushed west of the Mississippi into Iowa, Missouri, Arkansas and Louisiana, with 22 miles of railway in California. Today, of course, we have more than 228,000 miles of steam railroad in the United States.

During the period of railway expansion from 1840 to 1860, many more short lines were built. These generally were owned and controlled by local interests. They were built with various widths of gage. It was impossible to make a rather long journey without changing cars. Delays to passengers and freight were frequent. This situation prevailed for many years. It was as late as 1867 before anything resembling through service was inaugurated. Standardization of gage in that year permitted uninterrupted movement of cars between New York and Chicago by way of the Great Western Railroad of Canada. Gradually larger systems were formed by absorbing the short lines and standard gage became common the country over.

Prior to 1863 the railroads used light iron rails exclusively. In that year the first steel rails arrived from England. Two years later, in 1865, we began manufacturing steel rails in this country.

This brief excursion into early railroad history will suffice to remind us of some of the stages through which our national system of rail transport has passed in developing and attaining the strength and efficient service that enabled it to serve our country and the whole world so effectively in the days when it was threatened by international brigandage and despotism.

Advance Was Slow and Steady

Progress did not come all at once, nor as a matter of course, as many people seem to believe. Advance was slow and steady—many of the small steps were more influential on what was to follow than appeared at the time. The initiative and ideas, the am-

bition and energy of railroad men in each period—all striving to perform the transportation job a little better than it had ever been accomplished before—made all of this possible.

One improvement—sometimes relatively small—led to a larger one. The truth of the principle that the larger accomplishment is usually but the sum of a number of smaller tasks, each well performed, was demonstrated again, and then again.

In the days ahead our accomplishments will continue to depend as greatly on the skill and efficiency with which all the smaller tasks comprising the overall job are done, and, on the perseverance with which we seek always to improve current service and standards, making them more efficient and satisfactory than ever before.

The whole history of these United States is written, most dramatically of course, in the sufferings and deprivations and hardships of our forefathers. The foundations of our great nation were the faith, courage and perseverance of its founders. Many generations of Americans have been true to these great traditions. They made their own security, carved out their own futures, and built for us the strongest and finest nation the world has witnessed up to the present day.

What of the Future?

Well, in looking towards the future, it is not my purpose to sound any note of discouragement. On the contrary, I hope you may find encouragement in something I say.

We are on the threshhold of an undisclosed future. Many of our people want to abandon the heritages and traditions of the past. They seek, in short, an easier road to personal achievement and success—with the whole journey through life underwritten by the government of the United States and the United Nations.

I cannot recall, in my lifetime, any period when so many people are indifferent to the lessons and experience of all history, or so indifferent to the liberties and freedoms which have been bought with the blood of their forefathers and even the blood of their own sons and brothers.

We may as well use plain talk. We are a bewildered, confused people today—grasping at straws.

We talk a lot about fact finding. But the only facts we are looking for are those which will serve some selfish, immediate purpose. The harsh facts of realities we choose to ignore.

Difficulties Have Been Accumulating

The difficulties which beset us have not grown overnight. They have been accumulating for a long time. And to this accumulation of discontent, war has added its inevitable unrest and confusion. It is a fertile field for the trouble makers, reformers, brain trusters, parlor pinks, demagogues, bigots, and purveyors of foreign ideologies.

They have organized discontent, unrest, ignorance and selfishness to a degree of effectiveness that is, at long last, beginning to alert all red-blooded Americans. And therein lies the hope of the future.

Which path shall we follow—the one so clearly defined for us by American tradition, which challenges our initiative and our willingness to assume personal responsibility for our journey through life, or the path that holds forth the seductive promise of a luxurious joy-ride to Utopia?

It may be that we already have waited too long to face this issue, and may God help us if that be true! For my part, I won't admit it.

The key to our present dilemma, as I see it, is organization. The organization of pressure groups got us into it; the organization of a superpressure group which stands

for America First can get us out of it. The influence of each one of us must be made effective, and the influence of all of us, properly organized, will increase that effectiveness many times over.

Once there was a big riot going on in a certain community in Texas and the Committee on Law and Order in that community telegraphed the governor of the state for the Rangers to come and take charge. The governor wired that his rangers would be there on the eight o'clock train that evening. Well, the intimidated citizens met the train and watched one lone Ranger—a tall, raw-boned fellow—step off the train. The committee was dumbfounded and approached the Ranger with the question—"Where are the Rangers?" The reply of this lone Ranger was—"You have only one riot, haven't you? You have all that's necessary to take care of it."

One man, unafraid, who was on the side of law and order and in the right, was able to make his influence felt among a thousand or more people who had been cringing before mob rule.

Where Is America Going?

I appreciate that these remarks may appear somewhat foreign to the subject of railway engineering and maintenance. Actually they are not. This question of where America is going, is pertinent to every organization of thoughtful persons. It merits a place on top of the heap of your business of first importance.

I feel that I know this audience. You are an intelligent group of real Americans who came up the hard way. That is the way you would want it if you had it all to do over again. The things I'm saying are not at all new to you. You didn't achieve your present success by use of a seniority roster. Any one with initiative and ambition who gets on a seniority roster is whipped before he starts.

A deplorable situation is now confronting all industries, including the railroads. Thousands of young men entered the military service at or near the end of their college work and have remained in the armed forces from three to five years. They are now returning to civilian life after having lost the time they normally would have used getting themselves ready for their future place in industry, commerce or a profession. These men generally were young officers in the military forces. Some are recently married—others have one or two small children. They have no funds, and few have been able to gain any business experience during their service for our country. They now want to be located—want to put themselves in a position to get ahead—want to provide a home and security for their families, and in all respects to fulfill their responsibility as good American citizens.

At the Foot of the Roster

These men are now walking the streets of Chicago and other cities trying to find that job with a future, but what do they find? Generally, this is the answer they get from prospective employers: "We must, under our labor agreements, start you in at the foot of the roster as an office boy, or in the mail room, or on some equally small job paying much less than that necessary to keep a small family; furthermore, your advancement will depend solely upon the rate employes move up on the seniority roster —whether they are capable and qualified to do the job or not."

Just picture that outlook ahead of a young, energetic, college-trained man who perhaps worked his way through school before entering service. Let us follow his career further. Assume that he starts somewhere near the bottom of the ladder with a large industrial concern. He takes his place automatically on the seniority roster, and, in most cases, he must join and pay dues to a labor union. If he is ambitious or talented,

his union puts the brakes on him. He must not produce any more than his less ambitious or less talented co-workers. He must walk off his job if his union calls a strike. It must be pretty tough to come home from the wars and find that this is one of the "freedoms" he fought for!

He returns to find his homeland headed into a regimented economy. Instead of finding promising jobs and opportunities at every hand, plants are closed by strikes, or closed because of inability to produce at a profit under price ceilings that are absurdly unrealistic.

And who is responsible? Nobody but ourselves. We haven't liked what has been going on but what have we done about it? Virtually nothing, except to grumble occasionally, and occasionally go to the polls to vote. That is about all. Well, we had better bestir ourselves and bring some good sound thinking and aggressive action to bear on this situation before it is too late.

Better Public Understanding

The railroads earned their present standing with the public by actual performance prior to and during the war. If they are to maintain it, they must improve their public contacts, broaden public understanding of their problems, enlarge popular appreciation of their accomplishments, and develop wider sympathy and support of policies that will enable them to better serve the public.

We must, above all, maintain enthusiastic faith in the fundamental soundness of our industry. Had our industry *not* been sound, we would have failed in performance of the vital part we played in winning the war. We must be kept sound to play our important role in peace.

We urgently need real enthusiasm, not the "make-believe" kind, in our organizations,—enthusiasm that will attract people and sell them our ideas—ideas which we know to be honest and sound. When the public believes and backs such ideas, our problems will be easier to solve.

As railroad men, we must believe in ourselves and the railroad industry. We should have confidence in our ability to steer through the channels ahead as safely as did those who blazed the trail for us during the earlier days. They were not disheartened nor discouraged by difficulties. Their tools were crude in comparison with the effective organizations and equipment with which we work. They succeeded because they believed in themselves and were resolved to succeed.

Railroad men have been overcoming obstacles and difficulties ever since the first rails were laid on this continent. The fighting Seabees' challenging motto—"The difficult we do at once; the impossible takes a little longer"— might well have been lifted from the minds of railroad men.

The time comes to all when we may think that our role is most difficult. We get low and discouraged and seem to be looking down a dead-end street. We say to ourselves, "Why am I not given some measure of encouragement to go on?"

A Time To Get Things Done

Well, let's take a different look at things. You know and I know, after long years of experience, that it isn't so much what you get out of anything as it is what you put into the effort. I thought several years ago that the time would come when I could settle down; that all the tough problems would be settled and I would have nothing further to do but take it easy and "purr." If talk ever settled anything, I'm sure many of my problems would be forgotten, but I've found that many problems take much more than "talk" to settle.

Now I find that I'm not settling *down*—I'm settling up. This is because I'm still interested and want to keep on doing my little part. I want to see changes made to further improve our standards; to reduce our costs, and to improve our service to the public. I *like* to see things get out of the groove. Age doesn't affect my enthusiasm and desire to see more dreams come true. There is still enough energy left to look forward and press for such realization. Everyone is stronger than he thinks.

Application of the initiative, ingenuity, industry and confidence that have characterized railroad men from the beginning of our industry's development will produce the same results in the future that it did in the past. Men seldom accomplish more than they think is possible. They as seldom fail to accomplish all they are confident is possible. I can therefore prescribe no more promising treatment of our problems ahead than belief in ourselves, and confidence in our capacity to serve in the future as successfully as we have in the past. Surely what the railroad industry has done warrants supreme confidence in what it will be able to do in the years ahead.

We never dreamed that the railroads could do the job that was done during the war years. But, it had to be done—so we found a way. The future ahead of us—and it can be a glorious one—includes a most important place for our railroads. We must make it a magnificent place. But, we must win it ourselves. I'm confident we will. (Applause)

President Miller: We knew very well that the message that Mr. Johnston would bring us would be very fine, penetrating and full of truths and values, and he has the thanks of our Association.

In the report of your president a year ago, information was given to the effect that three of the committees of the Association, by act of the Board of Direction, were disbanded effective with the close of the Association year in March of 1945. There were included the committees on Signals and Interlocking, and on Electricity.

It was the judgment of the Board of Direction, after consultation with members of the committees affected, that the function of these two committees, namely that of reporting the activities of the Signal and Electrical Sections of the Engineering Division, respectively, could be handled more simply and effectively through a cooperative arrangement with the two sections.

Therefore, instead of receiving reports as formerly prepared by these committees, we will receive the benefits of the work done by the Signal and Electrical Sections of the Association of American Railroads through the medium of addresses by representatives of those Sections.

I take pleasure in presenting to you Mr. E. W. Reich, superintendent of telegraph and signals, Reading Company, Philadelphia, who will now address you in his capacity as chairman of the Signal Section of the Association of American Railroads. (Applause)

Address of E. W. Reich

Chairman, Signal Section, AAR, Philadelphia, Pa.

Prior to this year it has been your practice to have Committee 10, Signals and Interlocking, present a report of the principal current activities of the Signal Section, the members of Committee 10 being railroad officers who were active in the work of the section as well as the AREA. In lieu thereof, it is my privilege to present a report of work under way and to discuss the probable contribution of signaling to post-war rail transportation requirements.

Prominent in the work of the Signal Section is that of Committee I, Economics. Over a period of years this committee has conducted a continuing study, developing formulas covering the cost involved in stopping trains. In the fiscal year just past steps were taken to clarify the steam factor as applied and by condensing the formulas to simplify necessary calculations. The use by the railroads in engineering studies of the committee's cost data has been very gratifying and in supplementing this work, the committee has made available road freight locomotive utilization tables of various railroads in the literature of the section.

Centralized Traffic Control

No discussion of railroad transportation should be considered complete without reference to the acclaim for the job done by the railroads during the war and in connection therewith for the important part played by centralized traffic control. Records in traffic handled were established only to be surpassed again in the movement under all forms of train operation. However, the expanded use of CTC made it possible to bridge certain sections of roads which otherwise would have set up a bottleneck in the flow of traffic.

The contribution of signaling particularly CTC to the expediting of traffic during the war peak should focus attention on the facility of this system and, whereas CTC has forestalled and in many cases indefinitely postponed the need for additional main tracks in meeting increased traffic, the additional track capacity gained by its use should make possible the discontinuing of some multiple trackage in the event traffic decreases, or provide the means of obtaining an economic return in meeting competition of other forms of transportation.

The popular conception of CTC is that it consists of a desk arrangement of a panel-type model and control board, which catches the eye as it reproduces the railroad in miniature, with lamps to indicate the position of switches and the location of trains. Actually, CTC is an arrangement utilizing interlocking control of siding switches and signals, with automatic signaling between sidings, so that inherent in the system is the utility of interlocking with the protection of continuous track circuits and an automatic block signal system.

Originally CTC was regarded as a system which might be installed in a given territory simply because of the economic return, in that fewer attended offices were required, and where so applied it has justified the expenditure. However, experience has indicated possibilities of the system more far reaching if proper consideration is given to the physical arrangement of the road. In this connection Committee I presented a report on the economic advantages of signaling turnouts.

Modern high speed train operation demands improved track and signal indication operation. Some of the factors are as follows:

(a) Length of Siding.—With higher speeds and power-operated siding switches, fewer sidings are required for signal indication operation. As the sidings should be long enough to hold the longest train or two short trains they should be at least 100, 125, 150 cars and over in length.

(b) Sidings should be equipped with adequate signaling to indicate presence of a train in the siding with proper home and approach signals.

(c) So far as practical, sidings should be located outside of towns and switching areas. It has been possible to reduce the number of sidings from 25 to 50 percent on many signaling projects.

(d) The absolute signals at siding ends should be so located as to provide a good approach view, notwithstanding that to obtain this end it may be necessary to lengthen the siding.

(e) Crossovers and turnouts should be increased in size to permit higher speed operation.

(f) Water facilities should be provided on main track and siding for expedited traffic.

(g) Yard facilities should be adequate to eliminate switching on the main track.

(h) So far as possible yard tracks should lead off the siding in the rear of the clearance points.

(i) Adequate facilities should be provided for handling helper engines.

(j) Adequate facilities should be provided at yard entrance and exits to main track so as to eliminate delays to trains leaving and entering the yard.

These considerations, as you will infer, place emphasis on speed or, in the final analysis, reduced train hours; and it follows that stability of the switch structure to withstand the heavier stresses is essential to dependable performance of the control system. Likewise the signaling of sidings with associated track circuits will require the maintenance of the track with ballast resistance well within the limits prescribed for the reliable operation of track circuits, a requirement that is economically of major importance, as with low ballast resistance a larger number of track circuits will be required for a given territory, increasing installation and operation costs. In this last connection Committee I reported on the economies of coded track circuits, two miles in length.

Other Innovations

An interesting development in signaling is the remote control of absolute manual block system with continuous track circuits developed by the Wabash. This is a very interesting development and while not a substitute for CTC, it employs certain of the features of CTC and would appear to be advantageous for light traffic lines. The machine is a standard CTC type, so that if future traffic requirements are such as to necessitate power-operated switches, the facility can be added. A detailed description of the Wabash installation appeared in Railway Signaling for July 1945.

Still another interesting development is that of a simplified type of automatic block signaling installed in single-track territory of the Chicago, Rock Island & Pacific, based on continuous track circuits with signal protection extending from siding to siding, but with no intermediate signals such as would be required to permit trains to follow one another in a station-to-station block. Coded track circuits were used, thus eliminating the need for line wires and pole-line construction. The system, while it does not eliminate the use of train orders, provides protection comparable to any automatic block signal system and appears to be ideal for light traffic lines.

Summary

Summarizing, we have centralized traffic control, a system of interlocking and automatic block signaling which in expediting train movement through coordinated control inherently increases track capacity; manual block signaling, the Wabash System, with continuous track circuits and signals controlled from a CTC type machine applicable to light traffic lines; and the Rock Island arrangement of simplified automatic signaling, also designed for light traffic lines.

It is also worthy of mention that the use of CTC or panel-type machine has been extended to large interlockings commonly known as the all-relay type and for

the consolidation of interlockings where earlier practices were to install separate machines at control point for the remote control of adjacent interlockings.

During the war restrictions on material and scarcity of labor retarded the installations of automatic crossing protection and it is logical to assume therefore that as materials become available, this phase of railway signaling will become more active.

Advancements have been made by introducing refinements in circuit control to eliminate unnecessary flashing. Short-arm automatically operated gates with flasher signals on masts appear to offer a measure of protection required at certain types of crossings, and approach lighted signs controlling turns have generally been accepted as a means of protecting streets paralleling railroads with intersections adjacent to the crossing. More recently attention has been directed to the desirability of establishing a uniform warning time at crossings, irrespective of the speed of approaching trains. It is recognized that devices of this type might be warranted at certain heavily traveled highway crossings where the speed of trains varies, and at least one road has installed timing circuits so as to select certain speeds. It is the feeling of the section that this type of control should be developed further. However, its application should be limited to locations where rail and highway traffic is such as to require something more than the fixed control circuit.

Electronics

In the electronic field, a term that has been very much glamorized due to accelerated development and application during the war period, signaling has kept pace as evidenced by the development of carrier for CTC in which case the application of one or more carrier circuits on a pair of controls permits the breaking up of long sections of control, thus avoiding the need for additional line wires which otherwise would be necessary, to obviate undesirable delays in the transmitting of controls and the receipt of indications at the control point.

Another application of carrier has permitted its use in vital signal circuits by establishing different frequencies for each control and indication, all superimposed on existing line wires.

It is conceivable that war developments in electronic control now being released might find a place in signaling. Committee XI with a continuing assignment is investigating these possibilities.

While the technical engineering of communication requirements is not the function of the Signal Section, some mention should be made of the growth of inductive carrier and of space radio train communication.

Experimental installations of both types of communication covering end-to-end, train-to-fixed-point and yards have been made, and it is noteworthy that some rather extensive installations of a permanent nature are either now under way or authorized on a number of roads.

It is my purpose in the general outline of signaling presented in this report to indicate our thinking with respect to advancements in signaling and the part it will play in the post war era, also to call attention to the cooperation of all engineering groups required in arriving at a solution of rail transportation problems. In this connection I would like to express appreciation for the Signal Section of the cooperation between our respective committees concerning matters of mutual interest. (Applause)

President Miller: The magnificent and interesting address by Mr. Reich certainly shows how effectively is working the cooperative arrangement that I mentioned before introducing him.

On behalf of the Association, I want to thank you for bringing to us so much substance of real value.

Representing the Electrical Section of the Association of American Railroads is one who has been a member of our Association for 14 years and one who is well qualified to contribute much to our efforts and add to the information which we must have to enlarge and expand the effectiveness of the work of this Association.

It is a pleasure to present to you Mr. J. M. Trissal, superintendent communication and electrical engineer, Illinois Central System, who will now address us in his capacity as chairman of the Electrical Section, Association of American Railroads. Mr. Trissal! (Applause)

Address of J. M. Trissal

Chairman, Electrical Section, AAR, Chicago

As a representative of the Electrical Section of the Engineering Division, AAR, it gives me great pleasure to have the opportunity to tell you something of the activities of the section insofar as they apply to the application of electricity to railroads.

Wire Line Crossings

Several years ago the AAR was active in the revision of the National Electrical Safety Code, which is a national standard embodying, among other things, minimum specifications for the construction and maintenance of electric supply and communication lines when crossing over the wire lines and the tracks of steam and electrified railroads. After the Fifth Edition of the National Electrical Safety Code was approved, the Electrical Section entered into negotiations with the private utilities companies as represented by the Edison Electric Institute, in an attempt to formulate some principles and practices, as well as accompanying specifications, to be followed by these companies when their lines cross railroad property. These principles and practices and the accompanying specifications embody construction stronger than that specified in the National Electrical Safety Code, the utilities companies being agreeable to entering into a so-called "gentlemen's agreement" covering increased strength of construction but being unwilling to have the same requirements contained in a national standard which by action of state commissions might be made law. The AAR was represented on the committee handling this matter with the Edison Electric Institute by representatives from the Communications, Signal and Electrical sections, with one of the Electrical Section representatives acting as chairman. These principles and practices have been approved by the membership of the Electrical Section and General Committees of the divisions involved and have now been approved by the Association of American Railroads for publication in the Electrical Section Manual. The approval of these documents concludes a number of years of work and the documents themselves will constitute a useful treatise for handling wire crossing matters.

The electrical industry was greatly affected by restrictions as to the use of material during the war as rubber and copper, which were two of the most severely restricted materials, are essential to the proper operation of electrical apparatus. The Electrical Section was active in the study of substitute materials and in a number of cases was able to recommend the use of varnished cambric and synthetic insulations in place of commonly used rubber. Arrangements were made in conjunction with other

interested associations to have a temporary upward revision of the allowable current capacities in insulated wires. This revision was made without causing undue hazard and did result in substantial reduction in the amount of copper required. The use of capacitors and the raising of voltages of distribution circuits were recommended, both of which had the effect of reducing copper requirements. While a number of expedients developed during this period were of strictly a temporary nature, we believe that some of the methods and devices which were developed constitute a distinct improvement over those formerly employed and will result in continued savings and improved operation.

In common with the railroad industry in general, it was necessary to conserve man power to the maximum and numerous new controls were developed which made possible the automatic operation of facilities where heretofore it had been considered impossible or impracticable.

Electrolysis

A number of years ago the electrified railroads began to notice that anchor rods were rapidly corroding, presumably due to electrolysis. Other railroads where anchor rods were protected with a covering of concrete did not experience such difficuties and due to these differences in experience a request was made for a research allotment to determine the effect of electric current on concrete and try if possible to determine the amount of concrete necessary to properly insulate an anchor rod. The results which were obtained were described in AREA Bulletin 457, beginning on page 316. You will note that they were entirely different than had been anticipated. So far as the Electrical Section is concerned, all of the information which was obtained has been negative, but it is felt that there may still be more information to be gained by the continuation of these tests so far as other masonry structures are concerned. The results, however, have indicated to all of us that concrete foundations and anchor rods on electrified lines must be inspected at regular intervals to determine what damage, if any, is being caused by electrolytic action.

Electric Welding

We have been giving considerable attention to safety precautions to be followed in electric welding. It is known that when welding is done in shops and a. c. welders are employed, transient voltages of very high magnitude are sometimes encountered. These voltages are a function of the whole power distribution network, as well as the load thereon, and consequently do not lend themselves to accurate predetermination. Precautions must be taken so as to allow for the maximum voltages which may be encountered. This is a very perplexing problem, for if a workman is saddled with too many precautions and rules, the quality and quantity of his work are greatly affected. Certain recommendations as to safety measures have been made and others will follow from time to time.

On some railroads the chutes and pockets of coaling stations are kept from freezing by the use of electric strip heaters and the Electrical Section has made a preliminary report on this subject. A manufacturing specification covering electric snow melters for switches, etc., is now being prepared in collaboration with the Signal Section.

The electronic control of motors, while we do not look upon it as the panacea for all troubles that some manufacturers indicate, is being studied with a great deal of interest, as it makes possible some new methods of speeding up certain functions, primarily in shop work.

A good deal of attention is being given to the whole problem of lighting. Office lighting has become more or less standardized, although we anticipate some marked changes in practice when the new circular fluorescent tubes are completely developed. A study of lighting for mechanical department shops and terminals results in a great divergence of opinion as to requirements and methods. The use of high intensity mercury vapor lights in shops working in metal has in most instances proved highly successful. One of the most difficult mechanical facilities to light properly is that for servicing diesel locomotives. The very limited head room makes the ordinary type of lighting impracticable. While a number of experiments have been made, we are not as yet prepared to make any recommendations on this subject.

For a number of years the Electrical Section has been studying the corrosion of non-ferrous metals when exposed to the action of locomotive gases. The reports of the section on this matter have been very complete and it is anticipated that a final report on the last group of samples will be made this year.

Power For Communication

One of the new problems confronting the electrical departments of railroads is that of providing a reliable source of power for various communication circuits, such as carrier telephone and telegraph, as well as radio. While the power supply on locomotives and cabooses will be primarily the responbility of the Mechanical Division, we must be assured of an adequate and reliable source of supply at all fixed points. The importance of this matter is readily apparent when it is realized that a failure of one source of power out of the eight or ten normally employed in a 1000-mile carrier telephone circuit may render three telephone circuits completely inoperative. If batteries are used to supply power on cabooses for train communication work it will be the responsibility of the Engineering Division to provide proper charging facilities on caboose tracks. Inasmuch as cabooses are liable to be tied up at a number of points on a system this question of charging facilities may very well be of great importance.

With the continued increase in use of electric lanterns by train employes, the expense of batteries becomes an important item. A reliable method of testing batteries to determine remaining useful life offers an opportunity to effect substantial savings. Tests are being made of such a method and the results will be available in the near future. There appear to be possibilities of obtaining longer service life from batteries by a "depolarization" or "reactivation" process by means of current flow through the cells from an outside source. The results reported to date are somewhat conflicting and it is not as yet possible to present a true picture of the economics of the process.

I thank you for giving me the opportunity to present this summary of the activities of the Electrical Section, Engineering Division. (Applause)

President Miller: Mr. Trissal, on behalf of the Association, I express its gratitude to you for the valuable contribution that you have made to our thinking and activity. The cooperation of the Electrical Section is very much appreciated.

Award of Honorary Memberships

President Miller: The constitution of the American Railway Engineering Association provides for the conferring of honorary membership upon persons of acknowledged eminence in railway engineering or management. It also limits the number of honorary members to ten. At the present time there are four honorary members of our Association, and today we will confer two more.

We honor today Mr. Ralph Budd who has been a member of the Association for 37 years, is one of our past directors and now is president of the Burlington Lines; and Mr. J. M. R. Fairbairn, who has been a member of the Association for 36 years, is one of our past directors and past presidents and, until his retirement from active railroad service, was chief engineer of the Canadian Pacific Railway.

Unfortunately, Mr. Budd found it impossible to be present and has designated in his stead Mr. E. Flynn, executive vice-president of the Burlington Lines, to substitute for him.

Will the members of the Board of Direction and the past-presidents please find places on the platform? Past-Presidents Armstrong and Clarke will please escort Mr. Fairbairn and Mr. Flynn to the platform.

(Past-President Fairbairn and Mr. Flynn were escorted to the platform.)

President Miller: Mr. Clarke will please present Mr. Flynn.

Past-President Clarke: Mr. President: It is a very keen disappointment to all of us that Mr. Budd cannot be with us today to accept in person the honor which we are so proud to bestow. As you know, he is serving on the Wage Arbitration Board which is now meeting and so canont be here. I am sure that he regrets this as much as we do.

It is a privilege to present to you, even in absentia, a man who needs no introduction to the members of this Association or to those who are here today. He is recognized by everyone who is interested in any way in the great transportation industry as an outstanding railroad executive, and he is honored for leadership in the fields of railway engineering, maintenance and operation. He is known personally by a great many railroad men of all ranks and ages.

The early life of Ralph Budd followed much the same pattern as that of many other men who have attained success by their own effort and ability. And, for the sake of our industry and our country, I hope that those opportunities have not ceased to exist, although, as was hinted a few minutes ago by Mr. Johnston there is, perhaps, some danger that we may lose them.

He was born on a farm near Waterloo, Iowa, and his formal education began in a typical small country school. He was graduated from Highland Park College, Des Moines, Iowa, with the degree bachelor of science in civil engineering, and in 1899 went to work in the engineering department of the Chicago Great Western Railway which ran near the farm on which he was born.

He has been a railroad man, without a break, since the day he started but his experiences have been wide and varied, and he has served six different roads. He advanced rapidly on the Chicago Great Western but left in 1903 to go with the Chicago, Rock Island & Pacific, on which he served as roadmaster, general superintendent of construction and division engineer.

In 1906 he went to the Panama Canal Zone with John F. Stevens, as chief engineer of the Panama Railway. There he rebuilt the old railroad so that it might handle

the heavy traffic and construction work incident to the building of the Canal, and located and built the present railroad above the level of Gutan lake.

Mr. Budd left Panama in 1909 to go to the Pacific Northwest as chief engineer of the Oregon Trunk Railway, the Spokane, Portland & Seattle Railroad, and the Spokane & Inland Empire Railroad. There he met James J. Hill who in 1913 asked him to come to St. Louis as chief engineer and assistant to the president of the Great Northern. He later served the Great Northern as vice-president; executive vice-president and president. It was under his direction that the Great Northern built the eight-mile Cascade Tunnel and electrified 75 miles of line over the mountain range, a project which lowered the summit, lessened the grades and greatly increased the efficiency and economy of operation of that important transcontinental line.

January 1, 1932, Mr. Budd came to Chicago as president of the Burlington Lines. I shall not attempt to mention the many things which he has done during the past 14 years. Most of them are well known. Probably the best known but, perhaps, not the most important was the introduction of diesel-electric power and lightweight stainless steel equipment to the railroad industry the famous dawn-to-dusk non-stop run of the Pioneer Zephyr, Denver to Chicago, 1015 miles, average speed of 78 miles an hour, and the even faster 84 miles an hour non-stop run of the first Denver Zephyr, Chicago to Denver, operated east to west to demonstrate to his friend, Daniel Willard, that the Burlington had not just taken its toy train up to the top of the mountain and allowed it to drop into the valley.

His interest and efforts have not been confined exclusively to Burlington during the past 14 years. At President Roosevelt's request he served as transportation commissioner on the advisory commission to the Council of National Defense from May 1940 until that work was taken over in 1942 by the Office of Defense Transportation, and he is at present serving on the Committee for Economic Development.

Mr. Budd has been a member of the AREA since 1909. He is a past director and became a Life Member in 1944. He has done much for our Association, his outstanding contribution, perhaps, being the establishment of the plan under which our research work is being conducted. It was he who suggested such an organization to our Board of Direction and it was with his help and influence that the plan was put across with the Board of Directors of the Association of American Railroads. He has been greatly interested in the growth and development of that activity.

Mr. Budd said to me one day that he had been very fortunate in the men that he had met and the friends he had made, that many people had helped him throughout the years. I can say to Mr. Budd that he, in turn, has been of help to many, and we are glad to say that the end is not yet.

Mr. President, I present Mr. Edward Flynn, executive vice-president, Burlington Lines who at Mr. Budd's request will represent him and accept on his behalf honorary membership in this Association. Mr. Flynn!

President Miller: With the authority invested in me by the constitution of the American Railway Engineering Association and its Board of Direction I hereby confer upon Mr. Ralph Budd honorary membership in the Association, and present to Mr. Flynn, for delivery to Mr. Budd, a certificate indicating and symbolizing the high regard, esteem and affection in which Mr. Budd is held by this Association.

Mr. Flynn, I ask you to say to Mr. Budd that it is our high hope that his vision of this occasion may be a highlight in his life and experiences. We congratuate Mr. Budd, and thank you. (Applause)

Edward Flynn: Mr. President, I am sure that you and the membership of AREA know that Mr. Budd was very sorry he could not be here to receive this honorary

membership in person, but inasmuch as it was impossible for him to be here, I am very glad to accept the certificate and I will deliver it to him as promptly as possible. (Applause)

President Miller: Mr. Armstrong, will you kindly present Mr. Fairbairn?

Past-President Armstrong: Mr. President, to one who has known J. M. R. Fairbairn for well over thirty years, and for the greater portion of that time has been intimately associated with him, it is a high privilege to present him to you for his certificate of honorary membership in this Association.

John Morrice Roger Fairbairn was born in Peterborough, Ont., on June 30, 1873. After attending private school and high school in his native city, he graduated in civil engineering from the School of Practical Science, University of Toronto, Toronto, Ont. in 1893. While at school he spent two summers on railway surveys, and perhaps at that time was bitten by the railway bug. If so, it was not until some eight years after graduation that this inoculation took effect.

In the interval he acquired much valuable experience. For three years he was with various departments of the Canadian government, chiefly on surveys, maps, and plans. For one year thereafter he was engineer in charge of construction, in the vicinity of the then much smaller City of Montreal, of certain interurban lines which have since become part of the Montreal Tramways System. In 1897 he went west on land grant and mining claim surveys in British Columbia and became a licensed land surveyor in that province, as well as city engineer of Kaslo, B. C. In 1898 he entered private practice as a civil and mining engineer and provincial land surveyor at Kaslo and Greenwood, B. C., in the heart of the great mining district of Southern British Columbia. In the summer of 1900 he worked for a short time on grade reduction surveys on the Canadian Pacific Railway, and thereafter returned for another year to dominion government service as engineer in charge of a section of the Trent canal, an inland waterway extending from Georgian Bay on Lake Huron to the Bay of Quinte on Lake Ontario.

In the summer of 1901 he took up with the Canadian Pacific Railway his real life's work. Starting as an assistant engineer in a district engineer's office, he advanced rapidly through the positions of division engineer, district engineer, and engineer maintenance of way, and in 1911 was appointed assistant chief engineer, Eastern Lines. In 1918 he became chief engineer of the Canadian Pacific Railway, from which position he retired under the pension plan of the company on December 31, 1938.

In the twenty years during which he was chief engineer he encountered the trying times arising out of the close of World War I, the aftermath of that war, the new era of the 1920's, and the depression of the 1930's. In the railway world each of these periods presented its own grave problems, and one would have thought that his efforts through those years would have been an adequate life's work for any one man. In 1940, however, after the fall of France, he offered his services to the government of Canada, and they were accepted. With two confreres he undertook, for the Department of National Defense, the inspection of military camps. In 1941 he became director of works and buildings for the Department of Naval Affairs. In 1943, approaching the age of seventy, he again retired.

It would seem that he could have had little time or energy to give to the general advancement of the engineering profession. That this was not the case, however, may be judged from an abbreviated summary of the recognitions he has received. His Alma Mater has conferred upon him the honorary degree of doctor of science. He is a member and past-president of the Engineering Institute of Canada, and has received the Sir John Kennedy Medal, the highest honor that Institute has to bestow. He is an

honorary member of the Canadian Standards Association. He was an active member of the American Society of Civil Engineers, and has been awarded honorary membership by that society. He is a past member of the council of the Institute of Civil Engineers of Great Britain. He has been a member of the American Railway Engineering Association since 1910, and a past-president since 1926.

Mr. President, it is my privilege to present to you for his certificate of honorary membership in the American Railway Engineering Association, Dr. John Morrice Roger Fairbairn. (Applause)

President Miller: With the authority invested in me by the constitution of the American Railway Engineering Association and its Board of Direction, I hereby confer on Mr. Fairbairn honorary membership in this Association and present him with a certificate which is a symbol and token of the high regard, esteem, affection and love in which he is held by this Association. May the light reflecting from this occasion ever be aglow in his thoughts, his life and his memory.

Mr. Fairnbairn, with hands across the border, I congratulate you. (Applause)

J. M. R. Fairbairn: Mr. President, I am deeply conscious of the very high honor which you and the Association, through you, have conferred upon me this morning. I will always be extremely proud of it. It is a very high honor and I am deeply grateful for the indication of feeling that this conference of honorary membership conveys.

You may have realized from Mr. Armstrong's all too kind and somewhat extended history of my case that I have been active in quite a number of associations, societies, institutes and other things, and I can just say this, that I have never been in contact with any technical organization which began to give its members the same interest in their daily work that this Association does.

The Association, by its mechanics of operation, gives an opportunity to each and every member to participate in committee work. It gives him a chance to exchange his views, share his experiences with other members. From that he gains a great deal, gains experience and gains an intimate knowledge of fellow workers in his own field.

At the same time, the Association, through its committee work and the work of its individual members on those committees, produces a volume of valuable information which could be available in no other way, and that information is of enormous benefit to the membership of the Association, but not only to them; it is invaluable to the railway engineering profession throughout the world. There is no question in my mind that no other technical organization so fits its work to the daily work of its members and, at the same time, produces such great benefit to the railway end of the transportation industry. (Applause)

Some Modern Developments in Engineering Education

An Address Presented on Tuesday Afternoon, March 12, 1946, Preceding the Report of the Committee on Cooperative Relations with Universities

By Dr. Henry T. Heald

President, Illinois Institute of Technology, Chicago

During the last five years, the resources and energies of America's engineering colleges have been primarily devoted to war activities. Engineering education, like other segments of American life, has given a good account of itself. The end of the war presents a range of problems of equal magnitude and importance to the colleges, to the engineering profession, and to those industries which are largely dependent on engineering personnel.

War Time Service of Engineering Colleges

In addition to maintaining, insofar as practical, regular curricula for the education of engineers, the colleges carried a heavy responsibility for a wide variety of special war time programs. Among these were the engineering, science, and management war training programs which enrolled more than 1,500,000 students in special short term college level courses of importance to the war effort, the Army specialized training programs enrolling perhaps 200,000 men, and the Navy college training V-12 program with a smaller number of enrollees, many of whom completed degree work in engineering. Many military training activities of a character not ordinarily included in collegiate work were also carried on at engineering colleges.

War research contracts allocated to colleges and universities amounted to hundreds of millions of dollars. Thousands of faculty members left the campuses to engage in military duties, war research activities, industrial responsibilities or a variety of government posts.

Throughout the war the enrollment of regular students in American engineering colleges steadily decreased, with the lowering of the draft age and the discontinuance of deferments. In spite of the almost universal adoption of accelerated programs of study, the supply of fully trained engineers coming from the colleges continued to drop. In November 1945, the enrollment of civilian seniors was less than 25 percent of the pre-war normal. As a result, the country has already lost at least a college generation of engineering graduates. Even with the end of the war it promises to be 1949 before a normal number of graduate engineers is again produced.

As the colleges face the post war period, they find themselves with faculties depleted in numbers, and worn out through continuous teaching in accelerated programs. Nor are the prospects for the recruitment of faculty additions and replacements too good. Graduate students have been largely absent for several years and the brisk demand of industry for engineers places the colleges in an unfavorable competitive position.

Educational buildings and equipment have also borne the wear and tear of war without adequate replacement or maintenance. Consequently, the colleges face the future with its tremendous pent-up demand for their graduates, with huge numbers of veterans anxious to undertake college education, but with generally inadequate space for instruction, difficult housing problems, and a substantial shortage of well qualified faculty members.

The return of peace makes it possible for engineering educators to plan their programs with some degree of assurance. Whereas education during the war was largely characterized by the methods of expediency, it now becomes possible to think in more fundamental terms, and to give more careful consideration to the needs of the public and of the engineering profession. No thoughtful observer of education during the war can fail to conclude that in spite of war time pressures, the essential pattern of engineering education again has proved its strength. With years of sound experience, now tried under the pressures of war, there is little doubt but that the engineering colleges will continue to refine and improve their programs, and that engineering education will occupy an even more dominant role in the future.

The Engineering Curriculum

The report of the Society for the Promotion of Engineering Education Committee on Engineering Education after the War[1] has pointed out that engineering education has a responsibility to the public, to industry, and to the profession. This responsibility determines its aims and standards. It also has a responsibility to the students which determines its methods, since students must be regarded as individuals in developing their mind and character.

The report further points out that both of these responsibilities must be met within the limits ordinarily fixed by secondary school preparation and by college graduation. Into this period must be placed the training in sciences basic to engineering, the development of elementary technical skills, an introduction to the engineering method, the ability to read, write and speak effectively, a knowledge of social and human relationships, an understanding of the duties of citizenship, and some indoctrination in professional standards.

The attainment of these broad objectives during the period ordinarily available for an engineering course is a large order. It requires a properly selected group of students, a carefully planned curriculum, and a first class college faculty.

Traditionally, engineering education has been professional education of the integrated type. As contrasted with medical or legal education which seeks to superimpose professional work on a foundation of general education, engineering carries its two stems, the scientific-technological and the humanistic-social along in parallel. Thus although the four-year engineering curriculum includes a substantial portion of humanistic and social studies, these courses are distributed throughout the curriculum in a more or less integrated fashion, just as are the courses in mathematics and science with their technological applications.

The proper distribution of time between these two important branches of engineering education, together with the proper emphasis on subject matter within the branches, continues to engage the attention of engineering educators. There is general recognition of the importance of a better general education combined with greater emphasis on the fundamental sciences. This naturally results in crowding out some specialized application courses and in postponing others to the post-graduate years. Several institutions are seeking solutions to these problems by extending the undergraduate curriculum to five years in length.

Optional Curricula

In considering the wide variety of occupations and pursuits engaged in by engineering graduates and their varying interests and abilities, there seems to be very good

[1] "Report of Committee on Engineering Education after the War," *Journal of Engineering Education*, Vol. 34, No. 9, May 1944.

reason to believe that they will be better served by the development of optional types of curricula in the major engineering fields than by requiring all students to add an additional year to their course of study. The S. P. E. E. report suggests that engineering curricula might be divided into three patterns. The first would be conventional in character and would emphasize the scientific and technological studies in the fourth year. The second would be arranged to provide better preparation for those graduates whose interests lie primarily in the field of production and operation of industry. The third would be designed to provide broader and more fundamental preparation in scientific principles and methods. This option would enroll those students interested in research and highly creative professional activities who would frequently follow undergraduate education with graduate work.

At Illinois Institute of Technology, the faculty is now establishing such optional programs in the principal engineering departments. Traditionally, students in engineering colleges have been required to elect one of the principal branches of engineering and to follow a rigorous and almost completely fixed course of study within this field. Actually there is little evidence to indicate that a given student will be more successful as a mechanical engineer, for example, than as a civil or electrical engineer. The primary requirements for success are much the same for all, and the student's choice must be made largely on interest rather than from any inherent aptitude for one branch of engineering. It does, however, seem possible to identify with fair accuracy, at some point in the college course, those students who may have aptitudes leading them toward management, or sales promotion on the one hand, and those possessing superior scholastic ability, high intellectual interests, and the special talents of ingenuity or inventiveness on the other. For the former, an option is being provided which makes available a substanial amount of additional work designed to develop the individual's competency to deal with or direct other people. For the latter group, some of the more practical courses in the later years of the curriculum will be exchanged for advanced mathematical and scientific courses giving special attention to the use of mathematics in engineering analysis, together with an introductory experience in research techniques. It is expected that a majority of engineering students will be well served by the more conventional engineering curricula in which the later years emphasize technology. These are the men who will continue to fill the majority of engineering jobs in planning, in design, and in production. But the other two groups will be well prepared to meet real needs in a modern industrial society.

Engineering education has been sound training for future professional engineers and for a large group who hold a variety of positions in the broad fields surrounding the profession of engineering. There is no need for all engineering graduates to have the same type of curriculum. The rapid growth of industrial research in recent years is ample evidence of the need for preparing a portion of the best engineering graduates for this type of work. Management, sales and distribution are functions occupying the attention of a growing proportion of engineering graduates. Thus it seems that the development of the three options within each of the major engineering curricula will be a significant step in meeting modern requirements for engineering graduates.

Other Phases of Engineering Education

In addition to undergraduate education, several other areas of engineering education are destined to become increasingly important in the next few years. Postgraduate work in engineering, well established just before the war, has suffered a severe setback in recent years due to a lack of students. However, the demand for engineers

with this additional training has increased substantially and a rapid growth in graduate work seems assured. Increased interest on the part of industry will result in the establishment of many graduate fellowships to stimulate graduate training and research in engineering colleges. Part time graduate programs in several metropolitan centers are providing an excellent opportunity for many younger employed engineers to combine professional experience with graduate education.

Cooperative courses in engineering, although largely inoperative during the war years, continue to be effectively conducted in many institutions. The graduates of these courses have given an excellent account of themselves in industry's expanded war production program. Participation in cooperative courses merits the attention of any company interested in a continuous supply of engineers.

War experience has again high-lighted the need for large numbers of men with technical institute type of training. Technical institute education has been conducted by independent technical institutes, by correspondence schools, by proprietary institutions, and by certain colleges and universities on an extension basis. In many cases it has lacked clear cut objectives and definitive organization. The recent action of the Engineers Council for Professional Development in starting to accredit technical institute programs promises to make an important contribution in securing recognition and understanding of this important field of training.

The successful conduct of ESMWT courses during the war has pointed the way for increased educational work of an extension or adult education character. A number of institutions are expanding their work in this field and are taking advantage of closer relationships with industry to continue to meet specific industry needs for technical training wherever they are found. Many companies are providing the funds to conduct such classes.

Implications for American Railroads

The foregoing remarks have been directed toward some of the broad problems of engineering education. There are important implications in these comments which are of particular interest to the railroads. In the first place, the railroad industry in common with other American industries is, to greater or lesser degree, dependent on the graduates of the engineering colleges. Today there is an acute shortage of well trained scientific and engineering personnel. Reasonable estimates indicate that this deficit may easily be as great as 150,000 by 1950. This then, is a matter of real concern to the railroad industry.

For years railway work occupied the attention of a fair segment of the engineering profession. Railroad engineers have won wide recognition for their achievements and hold honored places in the profession. Many of our engineering teachers had their early professional experience in the employ of the country's railroads. No doubt times have changed. The railroad lines have been mostly built, and yet if the American railway system is to continue as a modern and efficient mode of transportation it certainly presents a wide range of challenging problems for engineers whether their interests lie in management, in research, or in operation.

It seems safe to predict that the enginering graduates of the future will be educated more broadly, have a better fundamental scientific training and, at the same time, will be less specialized in their fields than in the past. There will be even less emphasis on specialized curricula such as railway engineering and relatively few specialized courses relating to railroads will be incorporated in the regular curricula.

The reports of your Committee on Cooperative Relations with Universities bear out the well known fact that railroad employment is not at the present time attractive

to engineering graduates. This is not because the engineering colleges do not now produce men with proper training for railway engineering work. The railroads can certainly use the present day product of the engineering colleges, but the prospects of attracting many of them are poor indeed. It is interesting to compare the present interest in railway engineering with that in aeronautical engineering. A substantial share of the students entering engineering colleges today seek to elect aeronautical engineering in spite of the fact that employment opportunities for real aeronautical engineers are and will continue to be extremely limited. Although the aeronautical industry employs sizeable numbers of engineers, only a relatively few are actually engaged in airplane design. On the other hand, it has been years since any freshman, at Illinois Institute of Technology at least, expressed any interest in employment by a railroad.

No doubt it is the job of an engineering college faculty to direct its students to those fields in which the best opportunities lie; yet on the basis of past performance the opportunities for engineering graduates in the railroad industry do not look particularly bright. If this situation continues, the railroads are going to be in a less and less favorable position in competing for the output of the engineering colleges.

The solution to this problem will not be found in encouraging the colleges to give more courses in railway engineering. What the railways need are first class graduates of various modern engineering curricula, not men with specialized training. To secure these men, it will be necessary to convince the colleges and their students that railroad salaries, opportunities for advancement and for professional growth are the equal or better than those offered in other industries. The popular success story of the railroad president being a man who started as a section hand fifty years before may be a glorious tradition of the past, but it has little more appeal to the present day engineering graduate than reading the law in a country law office has to the law graduate.

The engineering colleges can be of real service in supplying well educated engineers and in assisting in research which is vital to the industry. If the railroads are to secure this assistance, it will be necessary for them to take advantage of procedures and practices already widely used by other industries. The railroads, too, will find it profitable to send representatives to the college campuses to interview and select the competent seniors. The railroads need just as realistic training programs for the college graduates within their organizations as do other industries. To fail to secure students for cooperative training is ignoring a source of exceedingly capable future engineering personnel. The railroads must encourage their employees to improve themselves through evening classes and extension courses, and support scholarships and fellowships if they are to meet the highly competitive demand for trained engineers. It is essential that adequate recognition of training and capabilities be given by higher salary scales and assurances of advancement. Only when these conditions are met can the railroads expect to attract their share of the ablest engineering graduates from our technological schools. (Applause)

President Miller: Dr. Heald, we thank you for a very inspiring and penetrating contribution to our thinking.

Here is the impression that was made on me and I imagine on many of us here. He stood on the line between what has been and what must be, and he had his back on that "what has been" and he is indicating that there must be cooperation between the place where we are trained and the place where we perform.

I want to thank you, on behalf of the Association, Dr. Heald, for a very, very excellent address. It was very, very timely.

Accident Prevention Programs For Highway–Railroad Grade Crossings and Trespassing

An Address Presented on Tuesday Afternoon, March 12, 1946

By J. R. Tenney*

Chairman, Committee on Prevention of Highway Crossing, Accidents, Safety Section, AAR

Over the past 55 years, that is, 1890 to 1944, inclusive, 386,000 persons lost their lives in connection with the operation of the railroads of our country. This total divided up roughly—3 percent passengers, 30 percent employes, 46 percent trespassers, 20 percent grade crossing casualties and 1 percent others. In addition to these fatalities, roughly 4,977,000 injuries were reported to the ICC during the same 55 years. Although no figures are available, the number injured during that period with disability under three days would probably amount to 25 or 30 million. The killed and wounded in the recent war constitute in the minds of all of us a tremendous loss, but a war of attrition over a 55-year period in our railroad industry has caused many thousands more fatalities than our greatest war, and several times the number of injuries experienced in that war. Deaths caused by railroad operation reached a high peak in 1917 and have been steadily becoming less since that time, except for a slight upturn during the years of World War II. In the case of injuries, this upturn has been quite substantial. However, at the present time, fatalities of all kinds in connection with railway operation are down 30 percent compared with the average number killed during that 55-year period, and 51 percent under the 1917 peak.

Two Persistent Problems

Two very persistent problems now plague the railroads with respect to casualties from railroad operation—the grade crossing problem and the trespassing problem, respectively. We note from the figures above quoted, that over a period of 55 years, the combined grade crossing and trespasser fatalities amounted to 66 percent of all railroad deaths. It will be interesting to note that for the year 1944, the last year for which statistics are available at the present time, the combined grade crossing and trespasser fatalities accounted for 68 percent of all deaths due to railway operation. This indicates that even though the over-all picture at the present time is 30 percent better than the 55-year average, these two causes account for the same or a little greater proportion of railway fatalities.

Grade crossing fatalities reached their peak in 1928 with 2568 deaths, compared with 1840 in 1944, giving us a reduction from the peak of 28 percent, but there has been a noticeable upturn in traffic accident deaths since the end of gasoline rationing.

The statistics point out the problem, and the Safety Section, Association of American Railroads, and the Steam Railroad Section, National Safety Council, decided to join in the promotion of a preventive program in an endeavor to reduce the number of accidents due to these causes. The top officers of the NSC, as well as the top officers of the AAR have given their approval, and President Pelley has already sent a letter inclosing copy of the proposed joint program to the chief executive of all the railroads of the association. Similar letters will be sent to the chief operating officers, and the safety officers of all the railroads in the association.

* Superintendent of Safety, Western Maryland Railway, Hagerstown, Md.

I wish to state here before going into the details of our grade crossing campaign that we are endeavoring to be meticulously careful not to encroach in any way upon the work of the divisions and sections of the AAR, charged with the engineering and technical work of grade crossing protection, realizing as we do that many millions of dollars have been spent by the railroads themselves, and other millions by federal and state authorities for the improvement of grade crossing protection and grade separation, and which work will continue as funds are appropriated by these collaborating agencies. All this work has been vital and has prevented thousands of fatalities at grade crossings. We cannot overlook the fact, however, that nearly two thousand persons die at grade crossings each year, and we believe there is a wide field in the realm of public education, engineering and enforcement directed toward bringing all vehicular traffic under better control than at present. It is toward this aspect of the grade crossing problem that our campaign is directed.

Funds Provided

Early in the war the National Safety Council, through its board of trustees, composed of ranking business executives in our country, raised by subscription a large sum of money known as the War Fund to Conserve Man Power, which was used to step up safety work in regular industry as well as war industry, and a portion of this fund was disbursed, under the direction of a railroad committee, in behalf of the grade crossing prevention work. Last year the NSC solicited what it calls a National Service Fund, to which the railroads contributed in the neighborhood of $150,000, a substantial portion of which they are willingly expending in the promotion of the present highway-railroad grade crossing and trespasser program.

While we as railroad men are primarily interested from a railroad point of view, we readily concede that the council should promote this campaign as an integrated part of its great overall public safety work. After all, grade crossing casualties represent less than 5 percent of all traffic deaths, and are viewed by the council from that perspective. The council, however, realizes that grade crossing accidents occupy a peculiar and important position from the standpoint of public reaction. They are far more publicized than the ordinary traffic accidents and, to the railroads, they are a great handicap in our public relations program. This has been well recognized by Col. R. S. Henry and his fine public relations staff in Washington, in the several discussions we have had on this accident prevention program.

While the death of two thousand trespassers per year does not present as unfavorable a public relations problems to the railroads as do the grade crossing accidents, it does effect our public relations to a great extent, and an anti-trespasser campaign is certainly worthy of our best efforts from a life conservation point of view.

Close Cooperation

The establishment of a closer relationship between the AAR and the NSC in the promotion of this grade crossing and trespasseer program should produce substantial results, and it is our intention to keep this alliance well integrated, so that as our work proceeds, each step will be taken with the approval of both the council and the AAR. However, it is recognized that the material to be issued, such as posters, pamphlets, school materials, movie trailers, etc., will be infinitely more effective if it bears the imprint of the National Safety Council than would be the case were it issued by the Association of American Railroads. In this view the Public Relations Department of the AAR concurs, and this aspect of the program is going ahead along those lines. It is easy to see that the NSC with more than 25 sections representing nearly all the

industries of the United States, as well as the schools aond colleges, is in a position to enlist all the various industries, many of the schools and colleges, and federal, state and local officers, as well as the many local safety councils throughout the country, in our grade crossing and trespasser programs.

The first nationwide move in this campaign will be the display of a grade crossing poster on bill boards in all parts of the country through the efforts of the General Outdoor Advertising Company during the month of April. These posters will be sponsored by state governments, local safety councils, and local industries, as part of their contribution to the overall traffic safety campaign. As near as the National Safety Council can estimate, that grade crossing poster will be displayed on several thousand billboards throughout the length and breadth of the United States under local sponsors, with no cost of any kind to either the National Safety Council or the railroads.

In cooperating with the NSC traffic accident prevention work, the advertising company dedicated the April traffic accident poster to the grade crossing program, and we submitted the artist's drawing of this proposed poster to the Public Relations Department of the AAR, and what that department considered very helpful changes from the railroad point of view, were incorporated into this poster as finally produced. This is another example of how we propose the campaign to proceed.

Animated Cross Bucks

While the artist was preparing the April grade crossing poster, the advertising company originated an idea which also met with the approval of our Public Relations Department. It submitted two small artist's drawings of the standard railroad cross buck sign in caricature. They animated the cross buck as a friendly guardian of the crossings and pointed out that an infinite number of situations are possible of creation centering around this character.

It was suggested that these could be produced in posters of various sizes and cuts for insertion in the Teachers Manual of the Association of American Railroads, and in some of the pamphlets to be produced by the National Safety Council and all distributed by various agencies and the railroads. It is believed that there is a wide field for producing good will toward the railroads in widely publicizing this friendly cartoon character. The originators of the idea contend that our standard cross buck sign could be changed from an inanimate object, often ignored, to the symbol of a friendly, interesting cartoon character. The possibilities of this and similar promotion methods will be fully explored by our respective committees.

This is an example of what the council can contribute to our grade crossing and trespasser work. Pamphlets for wide distribution are now being produced by the council and the number of these publications can be materially stepped up if all the railroads make large purchases to replenish council funds for the production of more and more of these materials.

It might be of interest to note at this point that, as I speak of the National Safety Council, it is a non-profit organization, and its work is multiplied as its members help it to multiply. They turn out manuals, pamphlets and posters of every description, and the more of those that are purchased, the more money flows back to the Council, the more posters and pamphlets are produced and sent into the schools and colleges and everywhere else.

The initial grade crossing pamphlets now in the course of preparation by the National Safety Council were submitted to the Public Relations Department of the AAR, and its criticisms and suggestions were given proper weight in the final makeup of these publications. This again is an example of the action that will be taken in

all similar materials to be issued in the future, so that everybody concerned with the preventive measures to be taken will have his proper say as to the character of the material that will go out for wide public distribution. It would not be amiss right here to remind all interested parties that the great nation-wide program of the council and its many affiliated national agencies designed to bring traffic accidents under control, will proceed unabated, and it is very much to the advantage of the railroad industry to have this real close working arrangement with the council, so that the views of the railroad men will always be taken into account in that part of the traffic accident picture relating to grade crossings.

To Organize in All States

It is the purpose of our joint grade crossing and trespasser committees of the AAR and NSC, repectively, to organize this work in all the states, beginning in those states where the grade crossing problem is the most serious. Already some very excellent work has been done in a group of southeastern states, particularly Georgia, and in the states of Mississippi and Minnesota.

I need not remind you that the railroads must work of necessity with all public authorities—national, state and local, in the matter of grade crossing protection. In many localities this is accomplished in a fine spirit of cooperation, but there are many places where this work causes much friction between communities and railroads. The divisions of the AAR concerned with this work realize that this is, and will continue to be, an ever present joint railroad and community endeavor, and they are successfully devoting their best engineering skill to this knotty problem. However, where the railroads and the National Safety Council have asked the cooperation of public authorities in a life conservation program with respect to grade crossing accidents, there has been some fine cooperation, particularly in the localities referred to. This encourages all of us to believe there are organized public and private bodies in the various states that are ready and willing to give us excellent assistance in the work of bringing grade crossing accidents under control. We should, of course, keep in mind that the grade crossing problem is just a small yet important part of the traffic accident picture, and all these agencies naturally want to include grade crossing accident prevention in their larger over-all traffic accident prevention.

I don't think that grade crossing accidents will ever be brought under control until traffic is brought under better control.

There is no question that the National Safety Council will do its part in this program. But the Committee on Prevention of Highway Crossing Accidents of the Safety Section, of which I have the honor to be chairman, realizes that we must do more than merely act as a coordinating agency between the National Safety Council and the Association of American Railroads; and we have, therefore, agreed to carry out our plans to promote this campaign within the railroad industry. I am addressing you today, because the engineering officers of all the railroads in this country can make a contribution to this program. Grade crossings present individual problems and, as each of you know, there are things that can be done to increase the sight distances at grade crossings, to improve the surface, and to suggest to railroad management where improvements can be made in grade crossing protection, either on the part of public authorities or the railroads.

Railroads Can Assist Locally

We are happy to state in this respect that the management of the National Safety Council is keenly aware that much assistance can be given to the railroads by

local public authorities in bringing the vexing grade crossing accident problem under better control through adequate enforcement action.

I might say here that the vice-president of the National Safety Council in charge of traffic and transportation, Mr. Leslie Sorenson, who for nearly 30 years has been traffic engineer of the City of Chicago has done yeoman work right around the City of Chicago and the suburbs in the way of giving civic cooperation and public cooperation on the part of the City of Chicago to the railroads. I think it augurs well for our campaign that we have as the vice-president of the National Safety Council in charge of this all-important work a man who realizes that there is an infinite number of things that the community itself owes to this grade crossing program, that the blame for grade crossing accidents isn't a problem of the railroads alone but it is a cooperating problem of every interest in the community, especially including the vehicle owners themselves.

It is known that some municipalities require by ordinance that gates and flashing light signals at railroad–street crossings be respected the same as the regular traffic light signals. While this will be one of the many promotional activities by the council, it also presents an almost unlimited field to influential local railroad officers, for inducing local communities to give this kind of cooperation for the mutual advantage of the railroads, the municipalities and the motoring public. We stress again that all of us as railroad people have a deep interest in the reduction of grade crossing accidents as a means of building up and holding public good will toward our industry. No railroad man can feel that the grade crossing problem, or the tresspasser problem, does not concern him, either in his capacity as a public spirited citizen or as one interested in his own industry.

Mr. C. J. Geyer, general manager, Chesapeake & Ohio Railway, and Mr. Bernard Blum, chief engineer, Northern Pacific Railway, have graciously consented to meet with the Grade Crossing and Trespasser committees of the Safety Section of this Association, and the Steam Railroad Section, National Safety Council, at council headquarters on Thursday morning of this week, to have brought clearly before them by staff officers of the council the details of our program and especially to have the benefit of their suggestions as to how this program should be carried forward. It is the intention of our AAR committee to keep all interested divisions of the AAR fully acquainted with the acitvities of our program, and to enlist their interest and help, both as railroad officers and as citizens of local communities.

It is not difficult to conclude that this is indeed a problem that looks almost incapable of solution, but the facts are that progress is being made in all fields of accident prevention and life conservation, and no program of this kind can be entirely incapable of solution. We are, therefore, determined to tackle it and do everything possible to resolve it. We realize that it will mean the enlisting of the efforts of millions of our citizens in government, industry, schools, farms, and other public activities, but with the great help the National Safety Council will be able to give, we are anxious to get on with the program. We realize, however, and so do the executives of the Association of American Railroads, that we cannot sit back and let the council do the job, as there are innumerable phases of the grade crossing and trespasser program that can be effectively promoted by the officers and men of the railroads of our country. It is a disturbing public relations problem, and the railroads have a vital interest from the standpoint of public goodwill, which all railroad officers throughout the country should recognize and join in alleviating. Our joint committees and the staff officers of the National Safety Council will endeavor to work out

the details of the program, but those details must originate in the day-to-day grade crossing picture, and our program will not succeed without active help and suggestions from the departments of the railroads concerned in the grade crossing problem. We, therefore, hope that out of this contact today and that of Mr. Geyer and Mr. Blum with our committees on Thursday will come a continuing working arrangement, whereby you can join us in the great amount of promotional work which will be necessary to insure any kind of success in reducing grade crossing and trespasser accidents. It is our hope to appear before the Signal Section of the AAR as well as other interested divisions and sections, to enlist the same kind of interest in the program that we are asking your organization to give us, and I thank you for this opportunity to present the program.

I wanted to drop that to you for the simple reason that I think under Mr. Sorenson's guidance this public campaign will present the grade crossing picture to the whole country in a very different light other than the fact the railroad is always responsible. (Applause)

President Miller: Mr. Tenney, your splendid address was most timely and penetrating, and this country needs a lot of that kind of information. I express the appreciation and the thanks of the Association for a most splendid and enlightening address.

The Place of the Railroads in the War

An Address Presented at the Annual Luncheon on March 13, 1946

By Brigadier General Donald Armstrong
Commandant, the Army Industrial College, Washington, D. C.

Many railroad men would probably be surprised to know how profoundly the development of railroad transportation has affected warfare. The American Civil War was the first great conflict in which railway transportation played a dominant role. Railways made it possible to have much larger armies in the field because they facilitated supplying these armies with food and munitions. In the total warfare of today railroads are even more essential for the work of the home front. The effective mobilization of our national economic resources depends on efficient transportation systems. Scientific research and production technology, national organization and political unity are all elements of our national strength. But without a well-run transportation system our population and the products of our mines, fields, and factories cannot be brought together to transform our economic potential into actual power. Consequently, railroads have been and will continue to be an essential element of our position in the international arena.

Whatever you gentlemen of the railway industry accomplish in increasing the efficiency of railroad operation, in maintaining the railroads at all times with a reasonable factor of safety to undertake the vastly increased demands of a national emergency, will be instrumental not only in winning a war if it comes, but, better, will help to prevent war. A deteriorated national railway system would be an invitation to an aggressor to strike this country with some hope of success. A potential enemy carefully weighs the probabilities of winning a victory. The present state of the railroads, their recent magnificent accomplishments is one of the deterrents that would make an aggressor think twice before attacking this country.

The Industrial College

The Transportation Corps under its chief, Major General Edmond H. Leavey, is, of course, the organization within the War Department which has the closest contact with all forms of transportation including the railways. The Industrial College, however, has the duty of studying and analyzing the railroad transportation system and its ability to meet another war load. The college is an institution where officers of all the armed forces are trained for industrial mobilization. We, therefore, look forward to a close contact with the railroads and other transportation agencies so that they will understand the prospective load of a mobilization. We need your interest in our problems and planning. We cannot permit the isolation of the armed forces from any element of our national economy. We confidently expect that the advisory committees to the Army Industrial College, now being established within the key industries of the United States, will provide the means for accomplishing these ends.

Why do we lay such stress on the railroads in our studies? First of all it may interest you to know that a careful analysis of production figures in the various combatant nations in World War II shows the relative magnitude of munitions production in 1944 to have been approximately as follows:

U. S. A.	100
Germany	40
U. S. S. R.	35
United Kingdom	25
Japan	20
Canada	5

If we could maintain this ratio of productive capacity of munitions, a threat of war to this nation would be diminished. Remember that it was actual volume of munitions produced and delivered that won the war. It was not mere economic potential. After reminding you of the accomplishments of the American railroads in the late war I shall tell you why the destruction of the German railway systems was so instrumental in insuring the defeat of that Axis nation. Need anything more be said concerning the part that railroad transportation plays in war?

The Achievement of the Railroads

The achievement of the railroads of this country during the war just finished has received much well-deserved publicity and widespread commendation. There is no need to dwell on those accomplishments before this audience. What the railroads did and how they did it is well known to you. A few brief comments regarding these accomplishments, nevertheless, may not be amiss.

Various statistical measures have been used to compare the service performed during this last war with earlier peak performances. The value of these comparisons and the accuracy of the conclusions that may be drawn from them, however, depend upon the degree of understanding exercised in using them. For example, the total cars of revenue freight loaded in 1944, the peak year of the recent war, numbered 43,441,000. This was less than the total revenue carloadings in 1918 by one million carloads. It would appear from these figures that the railroads did less well this time than during World War I under government operation. When it is pointed out, however, that the average load per car in 1944 was nearly 33 tons compared with 27 tons in 1918, it is immediately evident that the service rendered in the later year as measured by the actual volume of freight carried was considerably greater than in 1918. In fact, the tons of freight originated in 1944 were 18 percent above the level of 1918.

And this was accomplished with nearly 24 percent fewer freight cars, due to the greater speed of handling as well as the heavier load per car. The importance of this particular accomplishment is sometimes overlooked; but it meant that so much more iron and steel could go into the production of fighting equipment during a period when there was a critical shortage of basic materials and the construction of additional freight cars might have meant fewer tanks or guns. Not only were there fewer freight cars available in this war than in World War I, but there were also fewer locomotives, as well as fewer men to operate the trains. But not only were the cars more heavily loaded, the locomotives also hauled more of them in each train, and they were moved faster so that they did more work in a day than at any previous time in the history of the railroads.

Volume of Traffic Moved

The true measure of transportation service performed is the revenue ton-mileage, however, and accomplishment of the carriers gaged by this yardstick was truly remarkable. The total volume of traffic moved by all agencies of transport in 1944 was more than a trillion ton-miles compared with 540 billion in the last year before the war (1939). The railroad's share of this traffic increased from 62 percent before the war to 70 percent in 1944; the motor carriers accounted for approximately 5 percent compared with nearly 8 percent in 1939; inland waterways handled a little more than 13 percent and pipe lines about 12 percent. The effect of the allocation of 70 percent of one trillion ton-miles to the railroads as opposed to 62 percent of 540 billion ton-miles in 1939 was to more than double the volume of movement via railroad, and so to put a heavy strain on the available rail facilities. The fact that the railroads successfully shouldered this burden is in no small way to the credit of the maintenance engineers, whose constant vigilance and ingenuity in the face of tremendous obstacles created by flood, snow and storm, kept the plant of the carriers in a safe and sound condition. Without the work which you gentlemen did so effectively it would have been impossible for the railroads to perform their task; and without the railroads it would have been impossible for us to win the war. The vital nature of transportation in giving effect to the war effort has been pointed out on numerous occasions.

It was not until our air forces began seriously to disrupt the transportation system of Germany that the Nazi war machine began to go to pieces. In Germany inland water transport constituted a more significant segment of the transportation system as a whole than in this country, accounting for nearly one-fourth of the total traffic moved (21–26 percent); but highway transport, on the other hand, was of only minor importance. The German railroad system was one of the most adequate and best maintained networks anywhere in the world. Consequently, it was necessary in developing our air strategy to center our attack on the German railroads.

Railroads in Germany

The same means of improving the efficiency of rail transport were used in Germany as in this country. The utilization of all rolling stock was intensified—both locomotives and cars. New yards were constructed and vulnerable viaducts were paralleled with by-pass lines. In improving freight car utilization the Germans went further than we did in some respects in the matter of demurrage. We never reduced our "free-period" for loading and unloading below 48 hours, although we did offer inducements to release cars after 24 hours in some cases. The Germans started demurrage charges after 12 hours and subsequently reduced the free time to 6 hours and offered premiums for the release of cars in less than 6 hours. Restrictions on passenger travel, and staggering of hours were also instituted. Freight traffic was controlled under a strict pri-

ority system. German transport operations were maintained at a high level with only minor deterioration throughout the first 4 years of the war.

On our part, until late in 1944, transportation targets were attacked usually only as alternates to other target systems or as "targets of opportunity." Except for attacks related to ground operations the bombing of rail operations did not receive No. 1 priority until March 1945. Marked deterioration of rail operations began to be apparent as a result of the heavy air attacks of September and October 1944. These attacks resulted in heavy declines in traffic in the Ruhr area and the movement of coal to south Germany by water ceased. By the turn of the year marshalling capacity had declined to about 40 percent of normal, and there were 2000 trains delayed more than 6 hours by the end of 1944. Road blocks forced coal deliveries to decline on long hauls and resulted in the inability to return cars for loading. Since the German economy was powered by coal, production was reduced to the level that could be supported by fragmentary deliveries.

Although it was stated that the air attacks had not reduced the ability of the army to originate tactical moves in volume, it had caused serious delays and often prevented units from reaching desired destinations. As the weight of the attacks increased in the spring of 1945 transportation facilities declined further, and were prevented from recuperating. The flow of basic raw materials and components was completely disorganized. To the extent that lines could be kept in operation they were employed entirely for the immediate tactical needs of the Army. At the close of the war efforts were being made to repair yards that were actually under artillery fire.

Destruction of Railroads

The destruction of the German railroad system and the end of the war were practically simultaneous. No more eloquent proof of the vital contribution of rail transport to the war effort is needed than this picture of the German defeat. How immediately our own war effort would have ceased had some catastrophe destroyed our railroads requires little imagination to visualize.

The relative part played by transportation agencies other than the railroads was mentioned in the beginning, except for airways. The actual part played by the airways is shown by the fact that the ton-miles of freight carried by air never was greater than one one-hundredth of one percent of the total ton-miles moved. And air passenger transport, while substantial in the aggregate, actually amounted to only about one-half of one percent of the total passenger-miles for all agencies combined.

The importance of air transportation has been rather in the quality of the traffic carried and the service performed than in the quantity of traffic moved. Its importance on a quantitative basis, however, is increasing steadily, particularly in the field of passenger transport.

The Air Transport Command and the Navy Air Transport Service performed exceedingly valuable services during the war in carrying men and material to otherwise inaccessible points, and in meeting the peculiar urgency of war demands. The fact remains, however, that the railroads provided the backbone of the nation's transportation service. And their ability to provide a sustained effort on so great a scale was due in considerable measure to the high standards maintained by their engineers.

There Will Be No Time For Preparation

We are vitally concerned with the impact of the atomic age on our thinking and planning. We earnestly hope that the United Nations will prove to be an effective preventive of war. Nevertheless, the state of the world is such that actual and not

merely potential military strength is needed by this country to command respect among nations. We must endeavor, each in his own specialty, to examine the problem created by the atomic bomb and other new weapons of war. All elements of our national strength must be maintained at peak efficiency and strength if we are to withstand an atomic attack. If the future will see the kind of weapons in use that now are being developed, there will be little or no opportunity of increasing a nation's economic and military strength after the initial onslaught. In the atomic age, the need for greater dispersion will be critical. Dispersion means greater dependence on transportation. The evidence of the effect of atomic bomb attacks on Japan demonstrates that fortunately railroads suffer little damage from this form of attack. An outstanding authority recently told the students of the Army Industrial College, based on his observation of the bombing of Hiroshima and Nagasaki, that in case this country should be bombed, transportation would not be especially vulnerable. He said that it might be seriously interfered with, but a bomb of this power would probably not be used against transportation except to destroy a particular bridge or bridges. There would be a tremendous advantage over the past war in that a direct hit would not be necessary to destroy a bridge, a near miss would do. Railroad traffic itself is not damaged. The switch and anything above the ground is damaged, but quick repairs can be made. The switches were not fused, and there was no damage at all to the rails, roadbeds, even highways, or anything of that character. While rolling stock would be susceptible to damage, because of its mobility and normal disposition, probably only a small proportion of the supply of rolling stock—cars and locomotives—would be vulnerable. The rest would probably be out of reach of the explosion. Railroad wayside structures would likely be damaged, but most of them can be repaired or replaced relatively quickly. There might not be much traffic to move out of the bombed area but the transportation facilities could probably be brought into service promptly.

Our railroads may, therefore, face this new threat with comparative equanimity. The essence of the thought that I would leave with you is that upon the outbreak of war, the railroads should be operating at maximum efficiency. The conclusion is evident: Maintenance men have greater responsibility than they have ever had before for keeping the railroads strong and efficient at all times; management must never allow maintenance to be neglected, for if that occurs, the security, perhaps the very existence, of our nation is jeopardized.

Remarks at Close of Meeting, Tuesday, March 14, 1946

President Miller: This completes the consideration of the committee reports. Is there any other business to come before the meeting?

Past President Clarke: Mr. President, it is a custom of long standing for this Association to present a plaque to its retiring president. In itself it is of little intrinsic worth but in what it stands for and indicates it is of untold value to those who present it and to him who receives it. It stands for work well done, responsibilities faithfully discharged, duties completely fulfilled.

You have handled the affairs of this Association capably and well. This token which is now presented to you is intended to convey to you the esteem and affection

in which you are held by all members of this Association who have worked with you and under your direction.

For the third time it is impossible to present the permanent plaque, which is not yet obtainable. This temporary certificate, however, is given you in token and promise of that later plaque of enduring bronze which you will receive as soon as it is available.

This certificate which I now hand you reads as follows:

"The American Railway Engineering Association here records its grateful appreci ation to Albert Arthur Miller whose prudent guidance effectively advanced the proficiency and usefulness of the association during his term as president March 1945–1946".

President Miller: Mr. Clarke and members of the American Railway Engineering Association: I appreciate this very much.

Out of what Mr. Clarke said and what is behind this token, I hear something telling me that another link has been formed in a chain that we commenced to forge nearly a half century ago.

It seems to me I hear you all telling me, "Do not weaken that link by any thought or act of yours. Do not weaken your link or any other link in the chain that is being forged by the American Railway Engineering Association." It seems to me I hear that. I won't; I pledge you that I won't.

I pledge you further that I will continue to do all in my power, while I live, to strengthen every link, those already forged and those to be forged.

This and the feeling behind it and the thought behind it is very sacred, very near, very dear and very precious to me. I thank you all from the bottom of my heart.

Is there any other business? Mr. Lacher has just informed me that the total registration this year is 1337. There were 723 members registerd and 614 guests. This is the largest registration for a great many years.

It indicates to me that we are again out of the turmoil, coming together to work for peace, peacefully. It is also an indication to my mind that the American Railway Engineering Association is strong in all its sinews, and there can't be such an association without you and me getting together, staying together and working together.

Is there any other new business? I will ask Past Presidents Hastings and Layng to escort President-Elect Akers to the rostrum.

Installation of Officers

(President-Elect Akers was escorted to the rostrum.)

President Miller: Mr. Akers, you have been honored by the American Railway Engineering Association in your election as president during the ensuing year. It is the highest office in the Association. It is the greatest office, and it is the greatest honor that the Association can bestow upon you or any man.

Down through the years your predecessors have worn a mantle. It has never been changed, and it cannot be changed. It was fitted and fastened about half a century ago, and it doesn't need any other fitting or fastening because it covers the soul and not the body.

This Association is going to place that mantle on you today. I would express my sentiments in these words: The noble men of the American Railway Engineering Association are placing upon you this mantle for noble purposes. Wear it nobly. It lengthens with the years because it reaches into the depths for knowledge. It is reaching to the heights where truth, wisdom and values are revealed.

I present to you, Mr. Akers, a gavel. It is a symbol of authority. Use it wisely. I am now taking my place under the banner of your leadership. It will be your ex-

perience as it has been the experience of every one of your predecessors to be prompted and strengthened by the spirit of the American Railway Engineering Association. You will be well sustained.

Speaking for your predecessors I say to you this, Mr. Akers: Go forward. We have always gone forward. Keep us on the true path of the vision of the American Railway Engineering Association. I congratulate you. (Applause)

(President Akers presiding)

President Akers: Thank you, Mr. Miller.

Fellow Members of the Association: I am deeply appreciative of the honor you have bestowed upon me and pledge my best efforts. There is great inspiration in the Association history. I have been attached to that for some years, and you can't escape the inspiration. It is there. All you have to do is to receive it. It instills enthusiasm in all of us. I am happy to render this service as well as all others to this Association.

We are a service association and we are all engaged in service to the public, to our roads. A realization of this is evident by the excellent attendance at this meeting and by the earnestness of our members and the excellence of the reports. I congratulate you for that.

For the next year we will stress committee work more and more, increased research and development. We think that through research and development there are wide opportunities for advancement that will open doors for us, make it possible for us to render even better service than we would otherwise. We will make improvement wherever possible and do everything we can to prevent the weakening of the links that Mr. Miller referred to.

Our committee work has been well done but meetings have had to be minimized in number due to travel and hotel conditions and to the work necessary on our individual roads. I think everybody has been busy. We look forward to more meetings and feel sure that we will welcome that.

Our real work is done in committees. Through them our Manual is kept up to date. That is the thing by which we are known in so many places. Our Manual is looked upon as authoritative in its field, and we must see to it that it is so maintained by your critical, observant eye and mind.

There has been a large increase in train speeds, and requirements are different from what they were some years ago. Standards of maintenance are higher.

Research and development made possible by the fullest cooperation and support of AAR have been actively carried on through this Association for several years.

For 1946 there is an appropriation of $153,000. This kind of work is to grow in importance, and our plan is to further it to the utmost.

I thank you for your confidence. We will carry on, carry the flag proudly. Thanks to you, Mr. Miller. (Applause)

I think the Vice-President-Elect should stand and be identified—Mr. Chinn. (Applause) You know, of course, Mr. Geyer becomes Senior Vice-President. Will Mr. Geyer please stand and be recognized? (Applause)

We have three new directors. If they are present, will they please stand? Mr. Blackman, Mr. Armstrong and Mr. McBride. (Applause)

Is there any further business which requires attention at this time? Before bringing the Forty-fifth Annual Convention of the American Railway Engineering Association to a close, I wish to announce that the board of direction will hold a meeting in Room 4 at two p. m.

The convention is adjourned.

(The meeting adjourned at twelve-fifteen o'clock.)

Report of the Tellers

Presented Wednesday Afternoon, March 13, 1946

We, the Committee of Tellers, report the following as the result of the count of ballots:

For President

J. B. Akers 1010

*For Vice-President**

Armstrong Chinn 993

For Directors (Three to be Elected)

C. H. Blackman 570
S. E. Armstrong 386
J. S. McBride 385
J. M. Symes 334
H. F. King 298
E. C. Vandenburgh 287
E. E. Oviatt 286
J. E. Pringle 281
W. J. Hedley 264

For Members of Nominating Committee (Five to be Elected)

R. P. Hart 737
T. A. Blair 669
L. T. Nuckols 577
L. L. Adams 557
W. D. Simpson 551
O. G. Wilbur 423
C. H. Fox 410
W. H. Brameld 379
C. B. Bryant 374
F. J. Bishop 367

Respectfully submitted,

THE COMMITTEE ON TELLERS.

R. C. Bardwell, *Chairman*
E. G. Allen
C. M. Bardwell
W. O. Boessneck
C. M. Burgess
J. C. Bussey
F. G. Campbell
R. E. Dove
C. E. Fisher
W. H. Giles
O. E. Mace
M. F. Mannion
G. E. Martin
G. P. Palmer
W. C. Pinschmidt
L. S. Rose
H. E. Silcox
R. E. Warden
A. R. Wilson

* Under the provisions of the constitution, C. J. Geyer advances automatically from junior vice-president to senior vice-president.

Discussion on Cooperative Relations with Universities

(For Report, see pp. 225-241.)

(President Miller presiding)

(Chairman F. R. Layng (Bessemer & Lake Erie) read the foreword of the report on page 226. He then introduced Mr. Hastings, chairman of the subcommittee on Assignment 1.)

E. M. Hastings (Richmond, Fredericksburg & Potomac): This is just a brief report of progress. I will not read a word of it. I will ask you to tie it in with the report of this subcommittee for 1944–1945. It about rounds out the work of the subcommittee for the moment, from which I believe (and I think the belief is shared by other members of our committee) some rather definite conclusions and recommendations may be based.

It would hardly seem right or proper for me to attempt to elaborate in any way on the matters which have been presented to us by Dr. Heald.* He has said so many things this afternoon that have been in my mind for the several years since this committee was recreated in 1940 that I hope, when his paper is printed in the Proceedings, all of you will read it with great care.

The future now lies before us, but there is a door so wide open to those of us in the railroad industry that we should be very sure we find ourselves entering that door.

May I say to you this afternoon that we now have one of the great opportunities ahead of us in advising with these young men who are returning from the service, who were taken immediately from their college days into the service of their country and have had no opportunity, in many cases, to apply the education that they had secured. They are now back home and they need the guidance, direction and encouragement of those of us who are concerned with the future welfare of the railroad industry.

Dr. Heald, we are faced with a very great shortage of engineering graduates but there is a large fund of material in the graduates of recent years who have been used in the service of their country and can now be taken into the railroad industry and molded and shaped for the managerial and executive positions of the future.

May I plead with you men, as I have from year to year brought before you, the need of railroad management to recognize the potential, valuable material that can be secured through our cooperation with the technical institutions and through our employment of their graduates.

Chairman Layng: The second assignment of our committee will be presented by Mr. W. D. Faucette, chairman of the subcommittee.

W. D. Faucette (Seaboard Air Line): The report of the Committee on Cooperative Relations with Universities has been very well summarized in Chairman Layng's foreword on page 226, which I draw to your attention.

Need for cooperation with the universities and colleges of this country became very evident several years ago, and the committee work was restored and followed with zeal by the late Elmer T. Howson, of revered memory, and followed in its present form by Mr. Layng who takes a sincere interest in it.

He assigned to us certain spheres of activity, and that of our subcommittee was—Direct the attention of universities and colleges to any information and conclusions developed by the Association that may be of special interest or value to them.

* See address by Dr. Henry T. Heald, p. 574.

In order to link this matter in your mind clearly, without taking the time to go over the details—last year's report set forth the result of the initial questionnaire put out under the direction of the committee. This year there was a follow-up to determine what reaction, if any, could be obtained from these institutions. The reactions are presented on pages 229, 230, 231, 232 and 233, which I will not read. They are self-evident.

This report is not one that would provoke very much comment or discussion from the floor but is really food for reflection in human engineering and an attempt to bridge what seemed to be a growing gap between the colleges and universities of this country and the railroad industry.

It is not necessary to discuss the reasons why that gap may have grown but the facts as presented by the men with whom we made contact indicate there was a rather definite gap, and until some effort was made, that gap would not get extremely narrow.

That is reflected in a measure by Mr. C. C. Williams' answer on page 230 which I will not read but to which I invite your attention.

It is the purpose of the subcommittee which I represent and the purpose of the whole committee to make as close a contact and foster as cordial relations as possible between the industry represented in the railroad world, which is an enormous one and in peacetime probably does the greatest amount of construction, engineering, development and maintenance work of any one industry in this country.

It is necessary that the railroads take from these institutions the best talent, the best brains and the best trained material they can assimilate and use. It is unnecessary for me to say that, with the advances in technology, the demand on scientific attainments in the field of the railroad industry will be taxed to the utmost, because we are not alone in this field of transportation, but we are meeting in the air, on the water and on the land other instrumentalities of transportation that are going to use the best brains for engineering, for development, for transportation and for cheapness in operation.

It therefore stands to reason that, as an industry, we cannot afford to be found wanting in the use, integration and assimilation of the highest talent we can possibly get, and to get it we must use the men from these institutions, must foster a close relationship with them. We must always have a contact that will lead to a common ground, a common understanding and a common effort in the upbuilding of an industry which we all represent.

Chairman Layng: I will ask Mr. Lem Adams, the chairman of the subcommittee, to present the report on the third assignment.

Lem Adams (Oxweld Railroad Service): Last year we submitted a brief report of the number of replies we received on this subject—The cooperative system of education for railway service.

However, this year, in order to bring it more directly to your attention, we have divided this subject up into four subdivisions:

1. Railroads that favor the plan and now use it.
2. Railroads that favor the plan but have not used it.
3. Railroads that have used the plan and discontinued it.
4. Railroads that are opposed to the plan, but favor some other.

It was interesting to observe that, out of all of the railroads that had used the plan there was only one railroad that had reported discontinuing it for any cause. Obviously there are many good reasons to be advanced for the use of the coopera-

tive system of training students where they can also learn during their college work about the job that they intend to follow for their life career.

Until I got into this subject I didn't realize that there were so many universities and so well placed throughout the United States that were available for such training. We have heard Dr. Heald's address. His school here is devoted particularly to this type of training. Dean Eshbach is with the Northwestern Technological Institute. There are two large universities right here in our midst where men are obtainable through this source of training.

Our committee feels that it is well worth our serious consideration to look into the cooperative system and to further employ it upon our railroads.

I hope that each of you will take time to review the few pages in this report, to get the viewpoint of a few chief engineers and personnel directors on railroads that have been using this plan, and learn what they have been able to obtain from it.

Chairman Layng: Next is the report of Assignment 5. I will ask Dean O. W. Eshbach, chairman of this subcommittee, to present the report.

O. W. Eshbach (Northwestern Technological Institute): This report is so short, I will take the privilege of reading it. Our assignment was—Investigate textbooks and other material available for instruction in railway engineering and make pertinent recommendations thereon.

(Dean Eshbach then read the report on Assignment 5.)

Chairman Layng: Assignment 6: Unfortunately, the chairman of this subcommittee, Mr. Schwinn, is unable to be present, and I have asked Mr. J. B. Akers, a member of the subcommittee, to present the report.

J. B. Akers (Southern Railway): Report on Assignment 6—Develop conclusions and recommendations based upon a review of the reports of Committee 24.

(Mr. Akers then read the report on Assignment 6, and summarized the conclusions.)

Mr. Akers: I have only read a few of these conclusions. I commend them all to you. We hope to produce a program that will carry this very much further.

Chairman Layng: That completes the report of Committee 24.

President Miller: You have heard the report of Committee 24. Are there any who would like to make some comments in regard to this very important matter?

Mr. C. C. Williams, I understand, is here. If he is, he may have some comments to make.

C. C. Williams (Madison, Wis.): This is something of a surprise to me, Mr. Chairman, that you should ask me for comments. This is a committee work, however, in which I have been much interested through the years, having served for some time as a member of this distinguished committee.

As I looked at the committee in making its report, however, I was impressed with the relatively small number of men associated with universities who are present at the table just at this time. I think that is one of the difficulties under which the committee labors, namely that it is rather expensive for us poor college professors to attend all the meetings of the committee and to cooperate as fully as might otherwise be advisable.

It has often occurred to me that it would be desirable if some process could be made available by which men engaged on faculties of universities could attend meetings of the committee and contribute, we will say, their half of the counsel which the committee undertakes to assemble.

I think that the feature in collegiate education that Dr. Heald mentioned a few minutes ago, that is, the development of technical schools of less than university grade

will perhaps offer in the future some sources of recruitment of personnel in the technical fields, for railroads, that would be very useful. Railroad engineering is so different from other types of engineering and requires an amount of specialization, for which a great deal of the university course is not applicable.

So I am inclined to think these technical institutes or junior colleges of a technical sort in the future may offer to the railroads a source of young men for railroad service which will be better adapted to the needs of the railroads than are the graduates of the regular universities.

I think that the need of a superior source of personnel for the railroad is one of the most important needs. This has been recognized by the committee and by various writers on the subject, and it is a problem which it seems to me the railroads will need to solve—one of the very important and pressing problems.

Chairman Layng: I am very glad Mr. Williams called attention to the absence of some of our college and university members of the committee. I want to emphasize to you that we have, in addition to Dean Eshbach as a member of this committee, the following members of university or college faculties: J. B. Babcock of M. I. T., R. P. Davis of the University of West Virginia, R. B. Kittredge of the University of Iowa, C. T. Morris of Ohio State, W. C. Sadler, now in military service, University of Michigan. These men, almost without exception, have been very loyal in their attendance of our committee meetings and in serving on our subcommittees. I had letters from most of them within the last week emphasizing the great strain under which they are working at the present time, and which precluded their attendance at this time.

Mr. Williams, we well recognize the importance of having these men as a part of this committee, working with us on subjects so close to the interest of this Association. I feel sure that as time runs along we will have more of these college men associated with us in this work.

In closing, I might say one word, and that is this: If there has been any criticism that the chairman has directed to the members of his committee, it has been that the railroad members have not attended committee meetings as consistently as have the representatives from the colleges and the universities.

C. H. Mottier (Illinois Central): I was hopeful that someone would say something on the phase of the subject that I think is the vital issue. I did not intend to say anything but when Mr. Williams spoke, I thought of an experience that he and I had about 20 or 25 years ago.

I wrote to Professor Williams, then at Illinois, which was the natural thing for me to do as I am an alumnus of that institution. I asked him to send me the names of the seven best men in that year's class. I had them come to Chicago for interviews and hired six of the seven. The seventh got a better job than I could offer him.

I don't know where I would get today if I were to write to the head of the civil engineering department of the University of Illinois, tell him the salaries we pay and ask him to send me the seven best men in the class. I doubt if I could hire one of them.

In my own judgment, this problem of hiring young graduate engineers is one of the most important facing us. I assume the problem on our railroad is similar to that on many other railroads. In 1927, 1928 and 1929 we had a large engineering organization. Then came what some people called the depression and we reduced, reduced and reduced. I will tell you an anecdote relating to this force reduction.

Just prior to the depression, I had a large force of designers reporting to me, and it became necessary to reduce it almost to the vanishing point. I remember one day I had laid off seven good men. That night I was telling my wife about how serious the situation was. My little six year old son listened very intently. He finally said, "Daddy, do you have anything to say about who you lay off?"

I said, "Yes, Charles, that's the trouble. I have to pick them out and they wonder why I don't pick out the other fellow."

He studied a minute and then said, "Well, Daddy, you be sure and lay yourself off last." (Laughter).

In our force reduction we laid off the younger men, and today, outside of myself and a few chainmen and rodmen, the Illinois Central engineering department is made up almost entirely of what some of you would call old men. I imagine that the average age of engineers on the Illinois Central, including rodmen and chainmen, is around 54 or 55.

We went through the depression and we were lucky to hold our jobs. We were not able to hire any engineers during the war period. In fact, we have hired very few technical men in recent years. We have rodmen, chainmen and some instrumentmen who will some day consider themselves engineers but who do not have the fundamental training necessary to properly equip them as engineers.

As I see it, the problem is largely one of dollars. We talk about influencing our management and that is important, but I think we should begin with the chief engineers, the engineers of maintenance and the heads of our departments and educate them on the need of increasing the salaries of engineers.

We are now facing a very definite increase in salaries. I do not know how much these will amount to, but it is safe to say that salaries will soon be $25 or $35 above the present level. I am satisfied that we cannot hire competent engineers—and we should have nothing but the best—for the salaries we have been paying in the past.

What are we going to do about it? I think we are going to have to make up our minds that we will soon have to pay graduate engineers starting salaries around $250 to $275 a month, and agree, if they make good, to raise their salaries at the end of each year for two or three years in order to make our jobs attractive to them. After they have gone through this nursing-bottle period, they should become fixtures in our organization and be on their own. If we don't do something like this and compete with industry, we will not get the better grade of engineering graduates.

I think too many of us, chief engineers, engineers of maintenance, and heads of departments, who hire men, and who started as I did for $65 a month are letting our recollections of salaries of 25, 30 and 35 years ago influence our evaluation of present salary levels. If so, we are going to have to change our thinking.

I am not so much disturbed about our relations with the universities. They will turn out the engineering graduates if we will hire them, but we won't hire them at the rates we have been paying in the past. We are going to have to pay more money.

There are other features of this problem which are important. One is not to hire more graduates than you can absorb. For example, if you use technically trained men as track supervisors and you get 30 track supervisors on your railroad who are qualified to become division engineers and you only make one new division engineer every five years, you are going to create a congestion that is not a healthy situation. The problem of absorbing, developing and promoting men after you get them is a very important one.

Another problem is the creation of the right relationship between what I might term technical and nontechnical men in the same organization. These problems can be solved.

The main point I want to make is that this is more of a problem for us to solve than for the universities. A great many of us are going to have to change our thinking on the subject. We have to sell the idea to the management but we first have to sell it to ourselves. If we can sell the idea to ourselves, we will get some where but until we do, we won't.

President Miller: What Mr. Mottier said, is that a laborer is at least worthy of his hire. He points his finger at management; he absolves the universities altogether, and I think that is right. It is *our* problem. The universities mold men and minds, and they are fully qualified to do it. We take them and use them. It is our problem if we don't find the way to use them properly, and we certainly need them.

The railroads of this country rose to heights as the result of the engineer, whether we call him a pioneering engineer, a developing engineer, a locating engineer or a maintenance engineer. Transportation would be as simple as ABC, in my opinion, if the engineer were allowed to work to the end where he can say what is the economical thing to do.

C. H. Blackman (Louisville & Nashville): I think there is one implication in Dr. Williams' talk that we should answer. He implied that the railroads do not need graduates of universities; we need only graduates of technical schools, in other words, mechanics. He also implied that the railroads do need some first class, intelligent, well educated men, after he looked over his audience. (Laughter)

I think there is something there that the doctor is overlooking, and that is there is an opportunity in the railroad service for a well educated, first class, intelligent man. This committee ought to tell the universities so.

On our road we have an assistant vice-president who is from the maintenance department; the superintendent of transportation is from the engineering department; the general purchasing agent is from the engineering department. We have the best opportunity in the world for young fellows who are willing to start in at the bottom and to compete with the 35,000 other men for these top jobs. Unless they are willing to compete with them and make good, of course, they will stay at the bottom.

President Miller: I am going to ask, before we excuse the committee, that Mr. Layng try to bring together the thoughts expressed by Professor Williams and Mr. Mottier.

Chairman Layng: The committee are quite in sympathy with what Mr. Blackman has said. I think a careful reading of our reports will show we are not unmindful of the fact there are many positions available on the railroads for men, other than those who are strictly technically trained.

On the other hand, we are emphasizing the necessity for attracting technically trained men because of the very critical shortage of that type of man which faces us at the present time and for some time in the future. I do think, possibly, we can further emphasize to advantage the point emphasized by Mr. Blackman.

I think, too, I can endorse what Mr. Mottier has said, and some others who have commented on our report. The committee feels that its immediate problem is to get across to our railroad managements, first, the seriousness of the present situation and, second, the necessity of our top officers making definite plans to overcome the difficulties we are facing.

I might also say we have another subcommittee which did not file a report this year, under the chairmanship of Dean Davis of the University of West Virginia. This committee has been dealing definitely with this question of salaries, but the material is not yet far enough along for us to release it for publication. I am sure that all of you are just as much concerned as your committee is about the seriousness of the present situation and that you are just as anxious as we are to indicate the proper steps that may be taken to protect our industry in the future.

President Miller: Gentlemen, the leaven seems to be at work. I will review briefly what has been said here this afternoon. There is very little work of greater importance at this time for the railroad industry and for this Association than that comprised within the efforts of this committee. It is a work of greatest importance. The work needs a lot of cooperation on the part of all of us, for the future will be most vitally affected by what this committee is able to accomplish.

This is and of necessity must be a very hard working committee. The members of this committee are doing a splendid job. The committee is dismissed with the thanks of the Association. (Applause)

Discussion on Economics of Railway Location and Operation

(For Report, see pp. 49–65.)

(President Miller presiding)

Chairman M. F. Mannion (Bessemer & Lake Erie): The members of Committee 16 express sincere regret occasioned by the death on June 16, 1945, of its former chairman, H. M. Stout. We feel deeply the loss we have sustained and will miss the contributions he made to this committee. A memoir, including a brief sketch of Mr. Stout's career, is given on pages 50 and 51.

This year Committee 16 was assigned nine subjects and submits reports on three. Two of these reports are progress reports submitted as information, and one is a progress report including recommended Manual revisions.

Work has progressed on the other assignments. Subcommittees 2, 4 and 7 have made considerable progress and have collected data which is about ready to be presented in report form.

Because the chairman of Subcommittee 5 wishes to get away as soon as possible, we will present that as the first assignment. The report will be presented by Mr. Sillcox, chairman of the subcommittee.

L. K. Sillcox (New York Air Brake): Since you have already received the full report, we are taking the liberty of abstracting it. (He then read excerpts from the report.)

Chairman Mannion: The next report is on Assignment 1—Revision of Manual. This report will be presented by Mr. F. N. Nye, vice-chairman of the committee.

F. N. Nye (New York Central): With the approval of the Board of Direction, Chapter 21 of the Manual has been consolidated with Chapter 16, which thus becomes the Chapter on Economics of Railway Location and Operation, and new sheets were issued in the Manual supplement of 1945.

Because your committee noted the need for several minor adjustments in Chapter 21, arrangements were made to incorporate these revisions in the reprinting, and accordingly they are now published on page 51 for your consideration and ratification.

(He then read the matter on page 51.)

Mr. Nye: Mr. President, I move that these changes be adopted.

(The motion was seconded, put to a vote and carried.)

Chairman Mannion: The last report of Committee 16 is that on Assignment 3—Methods or formulas for the solution of special problems relating to more economical and efficient railway operation. Because the chairman of the subcommittee was called out of town, I will present the report.

This year the subcommittee undertook the study of the proper siding lengths for freight trains. It was felt that proper siding lengths was a timely subject, and the importance of this subject has been recognized more and more during the past few years.

Formerly sidings were designed to hold the average freight train of 50 to 80 cars. The operation of short trains on 50 to 80 car sidings was generally satisfactory with hand-operated switches. With the advent of heavier power and modern methods of directing train movements with power-operated switches, it has been found desirable to construct sidings as long as the longest train and, in some instances, often twice the length of the train.

With longer sidings and power-operated switches movements through sidings are often made without stops, thus eliminating many serious delays.

Another important factor was the adoption of longer turnouts to permit trains to enter and leave sidings at higher speeds.

The several factors entering into the determination of siding length are shown at the bottom of page 52 and on page 53. Each factor has been assigned a value. The formula for computing siding lengths is shown on page 53, and examples are worked out for 100, 125 and 150-car trains. These examples illustrate the use of the formula. Each railroad should substitute the values applying on a particular project. If more than one locomotive is used per train, if highway crossings are involved or other factors are modified, the formula should be changed accordingly.

This report is submitted as information with the recommendation that the subject be continued.

Mr. President, that concludes the report of Committee 16.

President Miller: Mr. Mannion, in dismissing your committee with the thanks of the Association, I wish to take this opportunity to express my appreciation of the service you have rendered as chairman which terminates at this time. (Applause)

Discussion on Yards and Terminals

(For Report, see pp. 91–104.)

(President Miller presiding)

Chairman W. J. Hedley (Wabash): As a part of the report you will find a memoir to Herbert Lawrence Ripley. Mr. Ripley was a member of Committee 14 for 22 years. He was its chairman for a three-year period at the time I became a member of the committee. He was a great inspiration to all of us. He was not only one of our older, respected members; he was also a working member. Only a short time ago he presented to you a report as a subcommittee chairman. We regret his passing but we are grateful for having had the opportunity of working with him and knowing him.

Our report this year covers two subjects, the first—Bibliography on subjects pertaining to yards and terminals appearing in current periodicals. As usual, it is almost wholly the result of the individual efforts of our indefatigable young Mr. E. E. R. Tratman. I suspect this work year after year by Mr. Tratman is a work of love on his part, otherwise I don't know how he could keep doing such an excellent job for us year after year.

Mr. Tratman, will you present your report?

E. E. R. Tratman (Wheaton, Ill.): On page 100 you will notice a new kind of bibliography. It covers the remarkable work that has been done by the military engineers in both the recent wars. Here is a list of about 130 articles that have been published in technical press on just that kind of work, which may be valuable in the future for reference.

The only other remark I would make is that the English railways seem to be having a great deal of trouble in getting passengers into the right train and right car, I don't know why, but they are trying all sorts of methods over there. They are using loudspeakers quite extensively, but they are not quite satisfied with them.

So at a recent discussion of the subject, the general impression was that better results would be obtained by platform enunciators. They have a system over there where one train is made up of cars for different cities. They have a board, maybe 6 ft. long, hung over the windows, with the names of all the stations that that car is to stop at, but lots of people get on them without any regard to the sign.

I remember an experience in Boston a few years ago. I was coming home. I got on the sleeper in the afternoon. Just before the train started, there was a sudden eruption of foreigners, with all kinds of bags and baggage, and they couldn't speak English, most of them. They simply took possession of the car and sat wherever they chose. It turned out they belonged to an opera company, coming to Chicago. The man who was in charge of them just simply piled them into the first car that he came to, regardless of the porter or the conductor. It took about an hour for the very polite conductor and a very disgruntled negro porter to get them all driven forward to their own car.

Chairman Hedley: We commend this bibliography to you as a valuable reference.

Our other subject on which a report is to be presented is—Produce terminals. That will be presented by Mr. W. H. Giles, subcommittee chairman.

W. H. Giles (Missouri Pacific): Last year your committee submitted a progress report on this subject. In the report it was pointed out that a definite line of demarcation exists between the services to be provided by the railway facilities and the services to be provided by the wholesale market facilities, and that the general term "Produce Terminal" should be considered to include at least two separate and distinct facilities.

The Manual now contains material on this subject. This report covers a rearrangement and slight expansion of that material. Since it is rearrangement, I will dispense with the reading of the details and read the paragraph which the committee recommend be included in the Manual to replace existing material.

(Mr. Giles then read the various paragraph headings.)

Mr. Giles: I move that this material be adopted for inclusion in the Manual to replace the existing Manual material.

(The motion was seconded, put to a vote and carried.)

Chairman Hedley: For your information, Mr. Giles has been appointed vice-chairman of Committee 14, effective following this convention. My term as committee chairman is now over. We may not have accomplished all that we had hoped during the last three years but they have been busy ones for all of us, and I appreciate very much the continual effort on the part of the membership that has enabled us to report to you something substantial each year.

To the members of Committee 14, I wish to say that my association with them on the committee is one of the joys of my life, and I have been greatly honored to have been chairman of the committee for a three-year period.

Mr. George Hand will be the new chairman of the committee. I bespeak for him your loyal support and cooperation.

This ends our report.

President Miller: Mr. Hedley, before dismissing the committee from the rostrum, I wish to congratulate you upon your service to the Association as chairman, which terminates at this time. We are very much indebted to you for your excellent leadership in the work that the committee has done during the last three years.

You brought up the matter of material in the reports down through the years and the reports are brief—many of the reports are. I tried to bring out in my address this morning the reasons for some such things at this time.

The committee is now excused with the thanks of the Association. (Applause)

Discussion on Water Service and Sanitation

(For Report, see pp. 73–89.)

(President Miller presiding)

Chairman B. W. DeGeer (Great Northern): The report on Assignment 1—Revision of Manual, will be presented by Mr. E. M. Grime, subcommittee chairman.

E. M. Grime (Northern Pacific): This year your committee submits one revision of the specifications as follows:

On page 13–38.5 under Specifications for Welded Steel Tanks for Railway Water Service, paragraph 603 states:

"An indicator shall be furnished and installed for the full height of the tank complete with suitable float, target and bronze metal sash chain."

It is proposed to change this to read as follows:

"An indicator shall be furnished and installed for the full height of the tank, of 10-in. channel iron complete with suitable metal float, target with guides, and bronze metal sash chain."

This change is submitted for adoption. I move that this change be made.

(The motion was seconded, put to a vote and carried.)

Mr. Grime: This year the glossary of water service terms as now appearing in the Manual has been revised, adding such new terms as required by developments in the art, and eliminating words or terms for which definitions are ordinarily available. The glossary as now recommended appears on pages 74, 75 and 76, except that the committee, in a final discussion after Bulletin 455 was printed eliminated the following eight words:

Hardness (Water).
Hardness (Pseudo).
Pipe, blowoff branch.
Drop pipe.
Service pipe.
Pipe offset.
Powerhead.
Valve, air relief.

After elimination of these last mentioned words, the committee recommends adoption of the revised glossary for publication in the Manual.

I move the glossary as now revised be adopted.

(The motion was seconded, put to a vote and carried.)

Chairman DeGeer: The supplemental report of Assignment 1—Revision of Manual, covering revised Specifications for Timber Substructures for Wood Water Tanks will be presented by Mr. H. E. Silcox who is chairman of the special subcommittee.

H. E. Silcox (Chesapeake & Ohio): Your committee submits revised Specifications for Timber Substructures for Water Tanks, 50,000 and 100,000 Gal. Capacity, and a plan for timber substructures for water tanks of 50,000 gal. (16 ft. by 24 ft.) and 100,000 gal. (20 ft. by 30 ft.) capacity, with the recommendation that the specifications and the plan be approved for publication in the Manual to replace the specifications shown on page 13–29 and the plans shown as Figs. 1306 and 1307 on pages 13–30 and 13–31, respectively.

The original plan appearing on page 49 of Vol. 46 was referred back to the committee for further study and has been revised to meet the objections and suggestions made after obtaining the collaboration of Committee 7—Wood Bridges and Trestles.

It is felt the report as revised is now complete and I move that it be adopted for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman DeGeer: Report on Assignment 2—Cause of and remedy for pitting and corrosion of locomotive boiler tubes and sheets, with special reference to status of embrittlement investigations will be presented by Mr. R. E. Coughlan, subcommittee chairman.

R. E. Coughlan (Chicago & North Western): During the past year your committee has been unable to report more than progress in the further development of preventives to intercrystalline corrosion.

The use of organic inhibitors and also sodium nitrate confirm the previous reports on preventives for this particular type of corrosion.

Considerable progress has been reported during the past year in the development of the welded boiler. The tentative plans indicate that several of these welded boilers will be in service on different railroad systems during 1946.

It is the intention of your committee to follow carefully the performance of these welded boilers in order to present a full report at a later date on this method of construction as a preventive of intercrystalline corrosion.

This report is presented as information.

President Miller: Unless there are some suggestions or discussion, the report will be received as information.

Chairman DeGeer: Report on Assignment 3—Progress being made by federal or state authorities on regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR—will be presented by Mr. R. C. Bardwell, in the absence of Mr. Van Hovenberg who is still in the Army.

R. C. Bardwell (Chesapeake & Ohio): Lieutenant Colonel Van Hovenberg who has been in the armed service for the past three years expected to be released this week, and after this meeting I believe he will be able to give you first-hand information.

The report on Assignment 3 this year—Progress being made by federal or state authorities on regulations pertaining to railway sanitation—is presented as information.

The activities of the United States Public Health Service on this subject have been divided into two distinct projects. First is the revision of the Public Health Service Drinking Water Standards as promulgated by the Surgeon General under the date of September 25, 1942. This proposed revision has been reviewed and approved by the Special Advisory Committee, State Sanitary Engineers organization and the Board of Directors of the American Waterworks Association. This revision should soon

be published. The revision will not materially change the standards as affecting the railroads.

The second project is the revision of the Sanitation Manual for Land and Air Conveyances in Interstate Traffic as promulgated by the Surgeon General under date of October 2, 1942. This has been the subject of several conferences between the Joint Committee on Railway Sanitation of the AAR and the United States Public Health Service, as the revised manual will become a legal requirement instead of recommended practice as formerly.

However, the committee was advised that the revision is intended to apply to new installations, that existing installations would be deemed satisfactory except where contamination was found and, under such circumstances, replacement would be required in accordance with the revised provisions of the Manual.

Of particular interest to members of this Association is the revision affecting hydrants which is published in this report and also the item on coach yard requirements, which is not materially changed. Severe restrictions are indicated for new watering hydrants which may involve considerable expense to the railroads.

The research study on the disposal of excreta from cars along the right-of-way and at terminals as authorized by the Board of Directors of the AAR last September has been started at Baltimore under the direction of Dr. A. Holman of Johns Hopkins University.

A progress report on this research should be available for the meeting next year.

President Miller: Is there any discussion or are there any remarks upon this report as made by Mr. Bardwell? I will say that he covered a subject that is becoming more and more important all the while. If there isn't any discussion, we will accept the report as information.

Chairman DeGeer: The next report is a final one on Assignment 6—Methods for taking water samples—which will be presented by Mr. R. M. Stimmel, chairman of the subcommittee.

R. M. Stimmel (New York, Chicago & St. Louis): Last year this subcommittee discussed general water samples and the collection of drinking water samples. The report for this year is on the particular subject of boiler water sampling.

Boiler water samples are usually collected for one of three purposes: First, for routine determination of the total dissolved solids in the boiler water; second, for routine control testing by the chemical department to check and regulate water treatment and boiler blowdown; third, for special investigations. Complete instructions for the collection of such samples are usually found in the methods for making the tests involved.

In general it may be stated that the boiler water sample should represent the circulating boiler water. The design of the boiler may have some effect on the circulation of the boiler water and, therefore, on the point where the sample should be taken.

For stationary boiler water sampling, it is usually possible to install a permanent sampling line which can be located at a point convenient and suitable for each individual case.

When a special blowdown sampling line is not practicable, gage cocks, water columns, and water glass drains may be used. A blowdown line other than the continuous blowdown line is not generally a suitable sampling point.

Sampling Equipment: The sampling tube should be as short and as small as possible. Special permanent sampling pipes may be installed. These should be located so they are below the surface of the boiler water to avoid getting steam in the water sample.

Sampling Procedures: The water column, and so forth, should be blowndown thoroughly before the sample is collected to remove sludge, stagnant water and condensate.

One of the principal sources of error in the sampling of boiler water results from the flashing of water into steam. After the water column and drains have been blown down, the sample should not be collected for a few minutes to permit drains, etc., to cool down. The amount of flashing which may occur depends on atmospheric and boiler water temperatures.

The instructions which have been given for the collection of boiler water samples are of necessity general in nature. The application of the instructions to particular cases will depend on the judgment of the chemist.

The report is submitted as information.

President Miller: Gentlemen, you have heard the report. Are there any questions or remarks? If not, the report will be received as information.

Chairman DeGeer: Our next is the final report on Assignment 9—Methods of removing oily deposits from inside of locomotive boilers—which will be presented by Mr. J. J. Dwyer, subcommittee chairman.

J. J. Dwyer (Chesapeake & Ohio): The report on Assignment 9—Methods of removing oily deposits from inside of locomotive boilers—is presented as information.

Considerable damage to fireboxes and staybolts has been ascribed to accumulations of oil inside of locomotive boilers. Efforts have been made to minimize or eliminate damage from this cause by periodic removal of these accumulations. This report describes a recent experiment in this direction and the results achieved.

The serious conditions reported have been found in locomotives equipped with open-type feedwater heaters operating on territories with long, heavy grades. It appears that the heavy oil accumulations result from the long downgrade drifts, when the drifting throttle is used while mechanical lubricators continue to function.

The ASME Boiler Code recommends a chemical formula of one pound of soda ash and one pound of caustic soda per 1000 gal. of water and boiling out for three or four days to remove the oil left in boilers where boiler men work in new or out of shop boilers, but these small amounts of chemicals were found ineffective on the heavy oily deposits referred to in this report, and during the wartime emergency, to take an engine out of service for three or four days, just for boiling out the boiler, would have seriously disrupted the transportation service.

The experiments described were carried out in boilers of 6000 gal. capacity, which were filled to the top gage cock or above, and were boiling for 18 to 20 hours with steam through the circulator and right-hand front blowoff cock, with the dome cap removed.

The principal formulas which were tried were first, 600 lb. of soda ash; then 3000 lb.; third, 1000 lb. of caustic soda; fourth, 200 lb. of sodium metasilicate and 20 lb. of a sulfonated-alcohol-type wetting agent; fifth, a mixture was tried composed of 250 lb. of trisodium phosphate, 100 lb. of sodium metasilicate, 20 lb. of sodium hydroxide, and 30 lb. of a wetting agent.

The results with the 600 lb. and 3000 lb. of soda ash were not particularly effective, and the 1000 lb. of caustic soda was only a little better. The 200 lb. of sodium metasilicate produced practically a clean boiler below the water line, and the sticky deposits above, that is the oily deposits above the water line, had become dried out and rather crumbly. The trisodium phosphate, sodium metasilicate, caustic soda and wetting agent combination, although better than the soda ash or the caustic

soda, was not as good as the metasilicate and wetting agent. This latter combination was then improved by leaving the dome cap in place and using fire in the firebox and boiling out under 100 lb. pressure.

This procedure has now been made standard practice on the railroad which sponsored the experiments described and very satisfactory results are being reported.

President Miller: You have heard a very interesting report on methods of removing oily deposits from locomotive boilers. Are there any questions or is there any discussion? If not, the report will be received as information.

Chairman DeGeer: The last is our final report on Assignment 10—Means of conserving labor and materials, including the adaptation of substitute non-critical materials, and specifications for the reclamation of released materials, tools and equipment —which will be presented by Mr. G. E. Martin, chairman of the subcommittee.

G. E. Martin (Illinois Central): This report covers means of conserving labor and materials. On page 87 reference is made to previous reports on this subject and the results obtained in salvaging used and abandoned materials.

The necessity for this practice continues to exist, and this committee now has a representative on the General Reclamation Section of Committee 3A, Purchases and Stores Division, whose duty is to recommend additional items for reclamation.

The use of cathodic protection for steel water tanks has been increased by several railroads, and it is believed this practice will reduce maintenance and permit tanks to be operated without taking them out of service for interior painting.

Shortage of labor for the past year has been critical in certain areas, but this condition has been somewhat benefited by the increased use of highway trucks and various types of labor-saving tools and equipment to reduce the amount of labor required.

The delay in peacetime production of equipment and material by the industrial disturbance now prevailing makes it necessary to continue any conservation practices applied effectively during the war period, as it will be some time before the supply will equal the demand for consumer goods in this country.

President Miller: Unless there are some questions or discussion of the report just made, it will be received as information.

Chairman DeGeer: This completes the report of Committee 13. It also terminates eight years for me as chairman of this committee, and I wish to thank each and every member for his support and hope similar support will be accorded to my successor, Mr. Grime.

President Miller: The chairman, Mr. DeGeer, told you something that I intended to tell you, but I am going to tell you anyway, because Mr. DeGeer has been chairman of this committee for a long while, and a real, good, substantial work has been done. The committee is to be complimented for the excellent work it has done during this period under your leadership. The committee is now excused with the thanks of the Association.

Discussion on Highways

(For Report, see pp. 67–68.)

(President Miller presiding)

Chairman A. P. Button (New York Central): The report of Committee 9—Highways—covers three assignments. The committee will first report on Assignment 1—Revision of Manual. Mr. A. S. Haigh, chairman of the subcommittee, is not here. I will outline briefly that recommendation.

(Chairman Button read the report on Assignment 1.)

Chairman Button: Those changes are merely in the interest of consistency. The first four figures show that the top of footing will be 6 in. above the crown of the highway; Figs. 907-B and 907-A show it as 12 in. above, and Fig. 931-A shows it 6 in. above.

It is recommended that these changes be made in the Manual, and I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Button: Assignment 2—Design and specifications for highway crossings at grade over railway tracks, both steam and electric—will be presented by W. J. Hedley, chairman of the subcommittee.

W. J. Hedley (Wabash): We present for your consideration Specifications for the Construction of Prefabricated Sectional Treated Timber Crossings. This specification is intended to cover the best design and practice of the present time, so far as we have been able to determine, in the manufacture and use of a type of grade crossing which is becoming more and more popular.

I will go through the list of topical headings for this specification and then offer it for inclusion in the Manual or for any discussion that is to be held on the specification.

(Mr. Hedley then read the topical headings.)

Mr. Hedley: I move that this specification be adopted for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Button: Assignment 3—Comparative merits of various types of grade crossing protection, collaborating with Signal Section, AAR, and Highway Research Board—will be presented by Mr. G. P. Palmer, chairman of the subcommittee.

G. P. Palmer (Baltimore & Ohio Chicago Terminal): This report is largely a matter of information based on further study that we have been making for several years on the merits of various types of grade crossing protection.

I won't take the time to read the entire report but simply call attention to the conclusion that we have shown on page 72, which reads as follows:

(Mr. Palmer then read the conclusion.)

President Miller: Unless there are some questions that you want to ask Mr. Palmer, or some discussion of what is contained in this assignment, we will receive the report as information.

Chairman Button: That concludes the report of the Committee on Highways.

President Miller: Mr. Button, your committee is now excused with the thanks of the Association. (Applause)

Discussion on Buildings

(For Report, see pp. 113–122.)

(President Miller presiding)

Chairman H. C. Lorenz (Cleveland, Cincinnati, Chicago & St. Louis): Committee 6 for the year 1945 was assigned six subjects. On the first —Revision of Manual— there is no report. The committee is now engaged, however, in revising that part of Chapter 23 assigned to Committee 6 and hopes to have it completed to present to the 1947 convention.

On color dynamics we offer a final report, which will be presented by Mr. H. M. Church in the absence of Mr. Angel, the chairman of the subcommittee.

H. M. Church (Chesapeake & Ohio): We have had very effective collaboration; during committee meetings at two locations we had the help of the research departments of several of the large manufacturers which gave us very useful information.

I have recently found in recent publications of the Bureau of Standards that the bureau has reviewed this same subject. Those members who are interested in this subject, involving improvement in paint and color harmony should obtain a copy of "Paint Mathematics, with Particular Reference to Federal Specifications." In this manual there is reference to the review made by the Bureau of Standards of color harmony, which is a term I prefer to apply to this subject instead of color dynamics.

The reference given by the Bureau of Standards is to a report dated in 1938, so it is not a new subject. It has reference to the National Bureau of Standards' letter circular LS-525, dated 1938. You will see in this report that it covers the different effects of color, how they are selected, their light reflection values, together with a little though important exhibit termed color harmony. One of the most direct conclusions is that given in paragraph 1 on page 117:

"Color painting has innumerable benefits and plays an important role in increasing production, reducing injuries, giving better working conditions, and uplifting the morale of the workers."

It is rather pertinent to this subject that our railroad has had occasion to make use of this color scheme in a particular portion of an erecting shop. This was later extended to the entire shop. Those who may be interested will find it very profitable to look into this particular application. This report is offered as information only.

President Miller: You have just heard the report. Any questions or discussion? If not, the report will be received as information.

Chairman Lorenz: The report on subject 4—Prefabricated buildings—will be presented by Mr. J. P. Gallagher, chairman of the subcommittee.

J. P. Gallagher (New York Central): Pages 118, 119, 120 and 121 do not refer to the report of this committee but are part of the report of the committee on Assignment 3.

The report treats on the subject in general and is submitted as a progress report and is submitted also as information only.

Chairman Lorenz: This concludes the report of Committee 5. There is no report on fire retardant coatings and on the means of conserving labor and materials.

I want to take this opportunity to extend my appreciation to the two subcommittees, particularly the chairmen, for assembling data for these reports during a time when they were heavily burdened with other work.

President Miller: You have heard the report, and the chairman has indicated it was submitted as information. If there is no discussion on any part of the report or reports that have been presented, they will be received as information.

This committee is really to be complimented on the work that it has done down through the years. This is the second chairman today who has indicated that there hasn't been as much work done as he or his committee wanted to do, for the good and sufficient reasons that have been indicated several times today, which I tried to cover this morning, and we all understand. The committee is excused with the thanks of the Association. (Applause)

Discussion on Maintenance of Way Work Equipment

(For Report, see pp. 179–204.)

(President Miller presiding)

Chairman C. H. R. Howe (Chesapeake & Ohio): The report of this committee this year consists of 11 assignments. No reports are offered on three of the assignments; on the other eight, reports will be presented by the respective subcommittee chairman.

The first subject for discussion this morning, Assignment 8—Diesel engines—will be presented by Mr. C. R. Knowles, the subcommittee chairman.

C. R. Knowles (Illinois Central): This preliminary report deals with the invention and development of the diesel engine, which is now some 54 years old, and embraces a general discussion of internal combustion engines, semidiesel engines and diesel engines. It also discusses the cost and weight of engines and the various details of operation, such as cycle of operation, fuel injection, starting and other details with regard to the engine. I must say in this connection, however, that the development in the diesel engine has been so rapid, particularly since the close of the war, that this report is already obsolete.

It is the intent to continue thse discussion of diesel engines, particularly with regard to the application to the various devices used in the maintenance of way.

Chairman Howe: The committee will now resume the regular order of the presentation of the reports, the first report being that of Revision of Manual will be presented by Mr. Edgar Bennett.

Edgar Bennett (Southern Railway): We only have one item for your consideration, and I will read the report.

(Mr. Bennett then read the report on Assignment 1.)

Mr. Bennett: I move that this be adopted by the Association.

President Miller: You have heard the motion, and the matter is for you to discuss and make suggestions about or inquiries. From my own viewpoint, I wish to indicate here that, when the emergency assignments were set up, the committees had to go into many things in the way of substitutes. I don't know whether you think as I do, that out of those emergency efforts would certainly come something of value that we would want to continue to use, and we have that in this motion.

(Mr. Bennett's motion was then put to a vote and carried.)

Chairman Howe: On subject 3—Manual of instructions for care and operation of maintenance of way equipment—no formal report is being submitted at this time. However, this is possibly the most ambitious and extensive work this committee has ever undertaken. It appears now that the final report will be ready for publication some time during this year in a special bulletin.

I am going to ask the subcommittee chairman, Mr. N. W. Hutchison to let us have a résumé of the progress his subcommittee has made.

N. W. Hutchison (Chesapeake & Ohio): As Mr. Howe has told you, the assignment is to prepare a manual of instruction for the care and operation of maintenance of way equipment. We had hoped to have this report ready for the convention this year but because of its nature, a great many revisions had to be made in it. Therefore, we will have to hold it over for next year, but we can definitely promise it will be ready at that time.

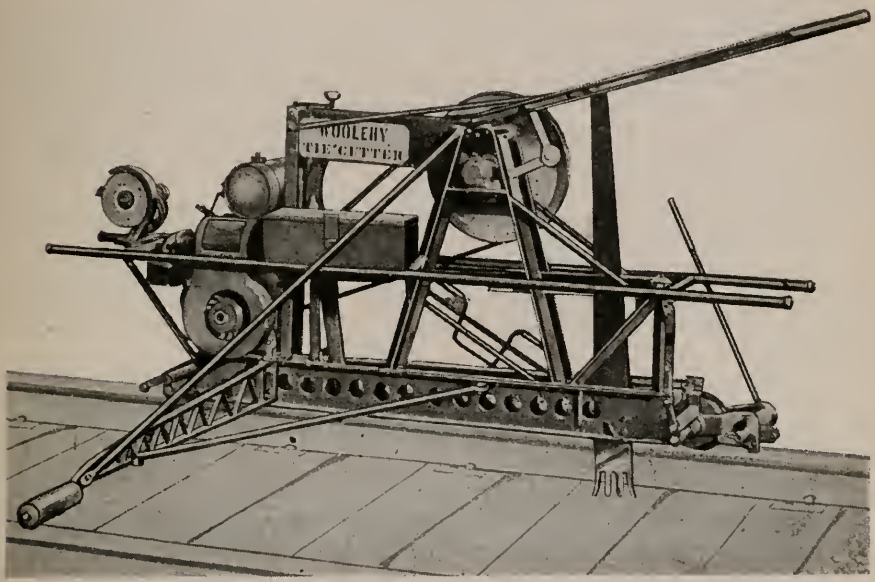
Chairman Howe: Assignment 4, which appears on page 180, covers tie cutting machines, and in reports of this character, it is much more easy to follow the descriptive text if it is accompanied by a photograph of the machine in question. Such a photograph was to have been included in this report but, unfortunately, the printer misplaced the plate, and it wasn't available at the time the bulletin was published.

It is now planned to print it in the Proceedings with the transcript of this discussion.

The chairman of the committee, Mr. F. H. McKenney, will present his report on this subject.

F. H. McKenney (Chicago, Burlington & Quincy): At the present time but one tie cutting machine is available. The general purpose of the machine is to facilitate the

removal of the tie by cutting it into three pieces. The cuts are made between the rails, the two end pieces removed by pushing them out from under the rails, and the center piece is then lifted out. The general idea is to remove the tie with a minimum of ballast disturbance and to provide a solid bed for the new tie.



The Tie Cutting Machine.

I will not take the time to read the report which consists of a description of the machine and the manner in which it is used. Your committee presents the report as information, with the recommendation that the subject be discontinued.

Chairman Howe: Assignment 5—Organization, machinery and tools for repairing maintenance of way work equipment. Mr. R. K. Johnson, the chairman of the subcommittee, will present this report.

R. K. Johnson (Chesapeake & Ohio): This is a final report, submitted as information.

In its investigation of this subject, your committee found it necessary to consider the matter of organization to be used in operating and maintaining the equipment. Therefore, a considerable portion of this report is devoted to the organization necessary for the proper application of machinery and tools in the repair of the work equipment.

The work equipment in use on the average railroad today for maintenance of way and structures work represents a very large investment. To secure the proper return from this investment, the equipment must be kept in serviceable condition and properly operated, it must be scheduled for maximum use, and the right machine must be assigned to each job.

The use of maintenance of way work equipment has increased tremendously in the past few years, but the organization and facilities to handle the operation and maintenance of the machines have not kept pace with this rapid expansion. As a result,

much equipment has been damaged due to improper operation and maintenance. Equipment is idle for long periods of time awaiting repairs. Inadequate repairs are made due to lack of facilities and trained men. Much idleness and abuse of the appliances have resulted from a failure to program the work and to use the machines for purposes other than that for which it was originally intended.

Since the service received from any given piece of equipment is governed by the manner in which it is maintained and operated, your committee recommends, in the interest of maximum utilization, that a systematic organization, properly manned and fully equipped, be installed to supervise the operation and maintenance of work equipment in the field and in the shop. Such an organization could be set up along the same general lines as those established on most railroads for the signal department or water supply department.

Chairman Howe: On Assignment 7—Hoisting equipment—the report will be presented by Mr. R. A. Morrison, chairman of the subcommittee.

R. A. Morrison (Pere Marquette): This final report is submitted as information. We believe some railroads have been slow in their substitution of power hoisting equipment for the laborious, hazardous and inefficient method of doing their lifting work with manpower.

Paragraphs 2, 3 and 4 describe the fundamental principles in lifting with mechanical means, as exemplified by the lever. The mathematics of block and tackle are explained in paragraphs 5, 6 and 7, followed by a description of the chain and electric hoists, with suggestions as to their use.

The next heading is Supporting Devices and describes the various supports readily erected and commonly used with the block and tackle, the chain and the electric hoist.

The balance of the report describes both on-track and off-track equipment now being used with satisfactory results, namely the derrick car, sand hoist, steam or air rail loaders, pile drivers, both on-track and off-track, and concludes with on-track and off-track cranes.

Chairman Howe: The report of subcommittee 9—Electromagnets—will be presented by the subcommittee chairman, Mr. C. E. Morgan.

C. E. Morgan (Chicago, Milwaukee, St. Paul & Pacific): Your committee presents this final report on Electromagnets as information.

We have given a brief description of the magnet and explained some of the variety of designs offered to the field of work in which magnets may be used. There is a description of the mechanical features of the magnet generator, including such elements as the advantages offered by separately driven magnet generators.

On page 200 will be seen a cross section of an electromagnet to enable the reader to gain some impression of how the magnet is constructed. The table at the top of page 201 will explain the relation between sizes, weights and generator capacities required, and the uses of the magnet. Also we wish to point out that the specific job for which the magnet is to be used is a very important item in the selection of the magnet.

Chairman Howe: Subject 10—Oil filters—in the absence of the subcommittee chairman, Mr. G. R. Westcott, the former general chairman of this committee, will present this report.

G. R. Westcott (Missouri Pacific): The report was prepared by Mr. C. M. Angel of the C. &. O. and contains some very valuable information, the committee thinks, and I am sure you will all agree with us if you will read it carefully.

Probably everyone present is familiar, to some extent, with the operations of an oil or gasoline filter. Most of your automobiles are so equipped.

The report is, of necessity, rather broad in scope for the reason that each type of filter is of a special nature and made to particular specifications, and to report separately on each type, giving the advantages and disadvantages of the various types, one against another, would be contrary to the policy of the Association.

The purpose of the filter is to keep the oil in proper condition and continually remove moisture, unburned fuel, dirt, carbon, metal particles and sludge, and to protect the engine from damage that would be caused by the presence of those things in the oil. Filters used for fuel as, for example, in the diesel engine, are designed to remove dirt and moisture from the fuel before it is used in the engine.

Taking the report in detail—on page 202 is a general description of the types of filters, followed on page 203 with specific reasons for oil filter use, and filters for fuel oil for combustion engines. On page 204 is a brief description of the maintenance of lubricating and fuel oil filters, and at the bottom of the page are five main conclusions summarized from the report.

It was thought that this report would give to persons interested in either fuel or lubricating oil filters a basic knowledge of such devices, so that a selection can be made that will best meet their requirements.

The report is submitted as information, with the recommendation that the subject be discontinued.

Chairman Howe: This concludes the reports of the subcommittees of Committee 27.

President Miller: Before excusing the committee, I want to make some comments with regard to both the subject matter and the work being done. It is one of the very important things that have entered our economic life in this country in the last 15 or 20 years. It has got to the place where some of the machines are doing a better job than we formerly did manually.

There is a feeling in some quarters that an attempt was being made to replace labor by the use of machinery. That is being dissipated, I think, to a great extent because maintenance men now realize that we are constantly raising the standard of our maintenance by the use of work equipment. With the pressure of competition that is on railroads, we have had to raise our standard of maintenance in order that we could have higher speeds.

The speed level in our country has been raised probably 21, 22 or 23 percent in the last 15 years. Work equipment is helping us keep up with that rather rapid rise in speed. So this committee is doing a very important work.

Mr. Howe, in dismissing your committee with the thanks of the Association, I wish to congratulate you on the work which the committee has done during the four years that you have been the chairman. We appreciate your service to the Association. The committee is excused with the thanks of the Association. (Applause)

Report on Roadway and Ballast

(For Report, see pp. 317–363.)

(President Miller presiding)

Chairman W. C. Swartout (Missouri Pacific): On Assignment 1—Physical properties of earth materials—the subcommittee did a great deal of very hard research work, but it was found that there were certain basic factors of which they and others in the engineering profession were ignorant. Therefore, a year ago, this committee under the chairmanship of Mr. F. W. Hillman, discussed at some length how to meet that prob-

lem. The result was a recommendation to the Association of American Railroads that $10,000 be set aside as a research project.

That research project is being carried out under the guidance of and in cooperation with another subcommittee of this committee. However, it seemed quite wise that Committee 1 await some of the definite results which we hope the research work will develop, rather than spend its time following up blind alleys. Therefore, that subcommittee has no report this year. Nevertheless, it is not resting on its oars.

Assignment 2—Natural waterways: That committee has done a considerable amount of work, but its report is not in the shape for presentation this year. However, we wish the assignment continued.

The next subject is Assignment 3—Culverts. Under (a) there is no report this year, although the committee has collected a large amount of printed material.

Assignment (b) will be presented by the chairman of the subcommittee, Mr. G. W. Miller of the Canadian Pacific Railway.

G. W. Miller (Canadian Pacific): The report of subcommittee 3—Culverts—comprises Specifications for Bituminous Coated Corrugated Metal Pipe and Arches. The first report on this subject was submitted to the Association last year as information and appears in Vol. 46.

After Vol. 46 was published, a few comments and suggestions were received by your subcommittee, and after further study the original specification was revised to clarify each of the questions which were raised.

Many of you will recall the trouble experienced some years ago with bituminous coatings which were improperly applied to corrugated metal pipes. In hot weather the material was often too soft to handle and in cold weather a slight shock would often cause the coating to crack and break away from the metal. This left a portion of the pipe exposed to the elements with possible shortening of its service life.

This new specification provides a most satisfactory method of testing not only the bituminous material before coating, but a field specimen can be easily secured and sent to the laboratory for inspection and test.

The apparatus which is illustrated in Vol. 46 is simple, inexpensive and easy to construct, and the specification has been used for a year by at least two large manufacturers of metal culvert pipe with success.

The proposed specification briefly includes the following. I am outlining this to you, realizing you do not have the specification in front of you as it was published last year in the Proceedings. It briefly includes the following:

1. A general description of the scope of tests.
2. Materials used and method of application.
3. Method of sampling test specimens.
4. The tests used to determine whether the coating will be satisfactory.

Mr. President, I move that the specification which appears on pages 493 to 501, inclusive, of Vol. 46 and as amended in Bulletin 458, page 319, Specifications for Bituminous Coated Corrugated Metal Pipe and Arches, be adopted and published in the Manual.

(The motion was seconded.)

H. R. Clarke (Burlington Lines): As chairman of the Manual committee, I raise the question as to publishing this in the Manual. We all know the importance of proper specifications, and I believe that these which the committee proposes are excellent.

However, it has always been the policy of the Board of Direction that specifications which may be published elsewhere would not be published in our Manual, in order to keep down the size of the volume. Are these specifications different from any others available? Are they to be found in ASTM standards, for example?

Mr. Miller: There is no other similar specification with the exception, I believe, of one which is used by the American Association of State Highway Officials, which is not entirely successful.

Mr. Clarke: This, then, is a new and distinctly different specification than any now available?

Mr. Miller: That is correct.

Secretary Lacher: I think Mr. Clarke had reference to the question as to methods of tests. We have in most cases referred to ASTM methods of test and eliminated from the specifications themselves the details of how the tests are to be made.

Mr. Miller: I would like to ask Chairman Swartout to enlarge on that, if he will.

Chairman Swartout: Answering Mr. Lacher's query, in the specification which was published last year and which, as Mr. Miller said, is being put forward at this time for adoption, there are three methods of tests which are ASTM methods and which are referred to merely by reference. They are not printed in our specification. For the purpose of completing the record, these are the following:

(He read the references to ASTM methods of test in paragraph 6, 7 and 8 on page 496, Proceedings, Vol. 46, 1945.)

Secretary Lacher: Am I correct in my understanding that these other tests that are described and illustrated are special ones for which there are no corresponding tests in ASTM standards?

Chairman Swartout: That is correct. These are original specifications, there is no other existing specification.

As Mr. Miller said, we started out preparing this specification from the AASHO "spec" and found it wholly inadequate to serve railroad use. It is a very good specification from the highway standpoint but not from the railroad standpoint. Therefore, we started from scratch and built up our own specification.

I might also add if the Association accepts this specification, it gives us in our Manual, in the specification on culverts, a complete cycle of specifications for corrugated metal products used for drainage.

(Mr. Miller's motion was then put to a vote and carried.)

Chairman Swartout: Assignment 4—Roadway drainage: Adherence to recommended practice. Mr. Brannon, the chairman of the subcommittee, was unable to be present. It is short and I will take the liberty of reading it.

(Chairman Swartout read the report on Assignment 4, and suggested the insertion on line 5, preceding the words "pole driving," the words "tie and," so that the clause would read ". . . such as tie and pole driving . . .")

Chairman Swartout: The real heart of our report comes next, and that has to do with the broad subject of stabilizing track. I know from my personal knowledge that this subcommittee has done a tremendous amount of work during the past year. I will ask the chairman of the subcommittee, Mr. George W. Payne, to present the report.

G. W. Payne (Missouri Pacific): This is a progress report on the stabilization of roadbed by the grouting method. Many questions concerning this method of stabilization are not answered in this report; for the simple reason that the answers are not known or at least the committee members are not in agreement on the answers. However, if you have read this report and there are any simple questions that you might want to ask, we will be glad to see if we can answer them. Is there any discussion?

Your committee hopes to obtain important information which may lead to definite conclusions from the work of the Engineering Division organization whose first progress report starts on page 324, right after our committee report.

A

Bernard Blum (Northern Pacific): I have not had an opportunity to read this report, and we have started to do some of this grouting work. I would like to ask if the pneumatic method of injection of the grout has proved entirely adequate as compared with the hydraulic or pressure injection of the grout.

I believe in a good many cases the individual roads, with their own equipment, have used the compressor. We on the other hand purchased a complete Koehring outfit.

Mr. Payne: I think the answer would be, yes, the pneumatic method has been satisfactory.

Mr. Magee of the engineering research organization will discuss the further report on this subject.

G. M. Magee (AAR): The Roadway and Ballast committee in 1945 initiated a research investigation aimed at the application of the principles of soil mechanics towards effecting methods of roadbed stabilization, with particular regard to the benefits possible through pressure grouting. This investigation is being conducted by the Engineering Division research staff of the Association of American Railroads in collaboration with the University of Illinois. We are particularly fortunate in having the services of Dr. Ralph B. Peck, research assistant professor of soil mechanics at the university. Dr. Peck has given a great deal of his time and energy to this work, and his services in planning a method of conducting the work and analyzing and preparing the test reports have been most valuable.

Dr. Peck attended Rensselaer Polytechnic Institute, receiving the degree of Civil Engineer in 1934, and the degree of Doctor of Civil Engineering in 1937. He studied soil mechanics in the Graduate School of Engineering at Harvard University. From 1939 to 1942 he was in direct charge of soils investigation and field measurements during the construction of the initial system of Chicago subways. Following this work, he was chief engineer of testing for Holabird & Root, architect-engineers for the Scioto Ordnance Plant. He joined the university staff in December 1943, since which time he has been engaged in university work, and has served as consultant on foundation problems for several organizations. Dr. Peck received the 1945 Norman medal of the American Society of Civil Engineers for his paper on "Earth Pressure Measurements in Open Cuts, Chicago Subway."

I am pleased to introduce Dr. Peck, who will now discuss the work of the investigation conducted last year for the Roadway and Ballast committee and described in the report of that committee appearing on pages 324 to 353, inclusive. (Applause)

R. B. Peck (University of Illinois): The purpose of my remarks this morning is twofold: First, to give you a brief, overall picture of the grouting process for stabilizing roadbeds and, second, to give you some conception of how the grout is actually distributed in the roadbed after it is injected.

We have chosen to start our investigation of roadbed stabilization by investigating the grouting procedure for several reasons. The most obvious, of course, is that it is a very popular procedure at the present time, and we are able to get a large amount of field information. However, it has certain other advantages, some of which appear to be inherent advantages.

Primarily, it is of interest because the injection of cement grout into roadbeds to stabilize them does not involve any large scale construction operations, does not interfere with train movements, does not require replacing or altering any part of the roadbed.

For that reason, if it should prove a successful method, it will certainly be an attractive one. Other methods of roadbed stabilizations have been attempted, including drainage and the driving of ties and poles. Under some circumstances these methods

have been successful; under others, they have been of temporary benefit or of no benefit at all. Whether or not the grouting method is likely to be successful, we do not as yet know, at least whether or not it will be permanently successful. But we do have enough information to give us some assurance that it is a promising method, and the chances are good that at least under some circumstances it will be economically satisfactory.

When we investigate unstable roadbeds, we usually find certain rather definite conditions. We find, first of all, a clay subgrade. We find the presence of an excessive amount of water, and we find that the upper part of the clay subgrade has become soft under the action of traffic, has mixed with the water and has worked its way upward into the ballast.

Under the action of the traffic, the ballast itself has been pounded down into the subgrade and, with the addition of new ballast under the ties, it will have formed ballast pockets in which water can accumulate more readily, and the process accelerates until we have a soft pocket that requires considerable maintenance.

I believe it is generally agreed that at least one purpose of the grouting procedure is to place a material in the lower part of the roadbed which will prevent the mixing of the underlying subgrade and the overlying ballast.

There may be other benefits. What these other benefits are, the extent of their importance, we also do not know for certain as yet but at least we can be sure that the aim of every grouting process is to get an inert material which will prevent the mixing of the subgrade and the ballast section.

To give you the broad picture of what is involved in the grouting process, we are fortunate in having some colored movies which were taken by Mr. John Poulter, a member of Committee 1, and which we are able to show through his courtesy at this time.

(At this point Dr. Peck presented an oral synopsis of the report on pages 324 to 353, with the aid of lantern slides as well as motion pictures. He then continued as follows:)

Dr. Peck: These pictures have given you an idea, I think, of where the grout goes when it is put into the roadbed. At the present stage of our investigation we have been largely concerned with finding out these facts. Our first interest has been to learn what happens to the grout when we put it in. We have not yet reached the stage where we feel that we can say where the grout ought to be to do the most good, and we are not in a position as yet to say that the various techniques which have been adopted should be improved or altered.

Our intent has been to get records such as you have seen in these sketches and to supplement them with detailed accounts which tell us everything about the grouting process at certain locations chosen on various railroads where conditions are quite different.

At each of these sites, for example, we have made careful records of where the grout holes were, how much grout went into every hole, what the techniques were, what labor and machinery were necessary to do the job, and then what we found in the trenches.

The railroads are cooperating by keeping maintenance records quite accurately on these particular locations, and over a period of several years we will study those records to find out whether the improvement has been permanent and the extent to which the grouting procedure may have been justified.

Likewise, we will make additional trenches from time to time and find out what has happened to the grout as time passes, under the action of traffic. That is our scheme

for going at this investigation. We want to find out exactly what has happened. We want to find out what the costs are; what the reduction in maintenance actually is.

When we have obtained that information, we feel that the various controversial points about techniques of grouting and about the places where grouting can be used successfully and where it is perhaps not a successful method of treatment will resolve themselves. We will not have to answer those questions by discussion or by opinion but we will be able to let the facts speak for themselves. (Applause)

Mr. Payne: I have a second report to present. Treatment of retaining structures begins on page 1-66.01 in the Manual under the heading and subheadings

603. RETAINING STRUCTURES

A. CRIBBING

B. WALLS

The present assignment, 5(b), covers a third and last section

C. STRUCTURAL SUPPORT; STRUTS; PILING.

This report is submitted as information for suggestions for improvement. Criticisms and suggestions are earnestly solicited to the end that the material may be presented for inclusion in the Manual next year.

I have expected by this time there would be a lot of brickbats coming this way on account of this report but so far there haven't been any. This makes me a little fearful that the members have not read the report as they should. Is there any discussion? It is a better report than I thought it was. (Laughter).

Chairman Swartout: Report on Assignment 8—Signs: Specifications and plans for telltales—overhead and side. Mr. Drumeller was unable to be present to present this report as chairman of that subcommittee.

It has been our view that our Association represents all of the railroads of the country, from the strongest railroads with the highest standards to the weaker lines that have to build the most inexpensive structures that will answer the need.

These specifications and plans for wood construction were really initiated as a war measure to conserve iron and steel. However, since all the work has been done, type set and plates made, we present the report to the Association for inclusion in the Manual in spite of the termination of the emergency.

This supplements or complements the material now in the Manual which covers steel construction. The material now offered, which covers wood construction, will be found in the Proceedings, Vol. 46, 1945, pages 514 to 517, inclusive.

In the absence of Mr. Drumeller, I move that the specifications for the wood construction be accepted by the Association and printed in the Manual.

I might say even the stronger railroads sometimes build a track which is of doubtful life, possibly to serve an industry, mine, with subnormal clearances, for which the steel construction, the more expensive type, is not justified. Then in that case they can apply specifications and plans in the Manual for the material which admittedly has a shorter life but is less expensive.

(The motion was seconded, put to a vote and carried.)

Chairman Swartout: I will skip over now to Assignment 11—Studies of test methods. The report will be presented by Mr. A. T. Goldbeck, chairman of the subcommittee.

A. T. Goldbeck (National Crushed Stone Association): This is a condensed version of the report on ballast tests. Since the service conditions to which railroad ballast is exposed are not entirely unlike those of highways, it has seemed logical to adopt highway tests for the determination of the quality of aggregates for use as ballast. During the past several years some of the older tests for ballast have been discarded and

have been replaced by the Los Angeles abrasion test. This test presumably determines in one operation the suitability of ballast because it simulates the impact and abrasion forces of service.

Up to the present time the Los Angeles abrasion test has been developed only for use with a sample extending up to 1½ in. maximum size, and it is still in the development stage so far as large size ballast material is concerned. Quite evidently further development is needed to determine its application to maximum sizes of 2 and 2½ in. A great deal of work has been done in an attempt to apply this abrasion test to these larger sizes, but thus far the results have not led to the standardization of the test beyond the 1½ in. maximum size.

Even though the test may become standardized, this will not establish the desirable percentage of loss for use in ballast specifications, and this can be done either by comparing the service behavior of a number of ballasts with their Los Angeles abrasion losses or possibly by the use of a device which will simulate service behavior with a sufficient degree of accuracy. Several years ago we endeavored to correlate the service behavior with the Los Angeles abrasion test, and we were not entirely successful, I think primarily because the personal equation of the individual reporters entered into the picture. A ballast which appeared good in one locality might appear to be a rather bad ballast in another locality.

With regard to this suggested device, it might consist of a box or bin capable of accommodating approximately five ties, spaced in a standard manner but of half the usual length. A standard heavy rail section might be attached to these ties which in turn would be supported on the ballast to be tested. The test would consist of repeated applications of a heavy, concentrated load to the rail, the settlement being continuously measured or autographically recorded. After a given settlement is reached, the track could be raised to its original position and the loading process and tamping could be repeated through a number of cycles to cause sufficient degradation of the ballast for measurement. This degradation could be determined by sampling the ballast and making a test for gradation. Finally, the results of such a simulated service behavior test could be compared with Los Angeles abrasion tests made on these same ballasts. A properly designed machine might be valuable for making service tests under controlled conditions and probably would speed up the work of comparing the service behavior of ballasts with the laboratory tests for quality. This machine is still in the dream stage at the present time.

At present the soundness of ballast is determined by the accelerated sodium or the magnesium sulfate test which is intended to stimulate the disintegrating action of freezing and thawing. This accelerated test is not entirely satisfactory in that some materials fail in the test but do not fail in service while still others are relatively sound as indicated by the accelerated test, but fail in service. Furthermore, all ballasts are not subjected to the same severity of exposure and, hence, it would seem that a variable percentage of loss in the specification for durability is needed, depending on the exposure conditions.

This briefly summarizes some of the desirable researches in the ballast field. Tests results could be obtained quickly if the needed personnel were available and a definite research plan were followed; otherwise facts will be obtained gradually and your committee must continue to rely on its best judgment in the writing of specifications.

This report is presented merely as information.

Chairman Swartout: The report on Assignment 9—Ballast specifications is quite lengthy. I have asked Mr. Walker to comment upon it.

Stanton Walker (National Sand & Gravel Association): The report of this subcommittee is presented as information only and has for its purpose the explaining of the present status of specification writing for ballast, and some of the reasons why there have not been more recent changes in the Manual.

It has been felt that the principal function of this subcommittee has been primarily that of acting in a standby position until additional information is developed, for the most part, information on test methods.

The recommendations of the specifications most readily evaluated are those covering grading. Grading is a tangible characteristic on which almost everyone dealing with ballast has an opinion. The review of specifications conducted in 1943, and published in the Proceedings, Vol. 44, 1943, indicates that most of the formal specifications issued by individual railroads are consistent with the spirit of AREA recommendations. That appears to represent tangible evidence that the suggested gradings are satisfactory. On the other hand, relatively few railroads have incorporated AREA recommendations bodily in their specifications and many railroads, which have modeled their specifications closely after AREA recommendations, have not taken into account recent revisions. It is suggested that, in the interest of simplified practice, railroads be urged to re-examine their specifications in the light of the current AREA recommendations.

Quality requirements for hardness, strength, durability, etc., are less readily evaluated than grading requirements. They present the problem of the significance of tests as related to performance in service. Ballast specifications, in common with other specifications, fall short of drawing a completely accurate line of demarcation between satisfactory and unsatisfactory materials. That, in part, is because of inadequacies in test methods and, in part, because the suitability of a given ballast may depend on conditions of use. More work needs to be done on this phase of the ballast specifications, much of which must await the development of further information.

The report goes on to discuss some test methods, modifications in test methods that are needed and, inevitably, it covers very much the same field that Mr. Goldbeck, who has been responsible for the development of test methods, has already covered.

Chairman Swartout: That concludes the report of Committee 1.

President Miller: Before excusing the committee, I want to bring to you some thoughts on the subject discussed this morning by Dr. Peck, namely, roadbed stabilization.

As our traffic is being expedited, there is greater pressure on us for tracks that are good for higher overall speeds, which means that a lot of so-called "liability" or "slow-order" spots have to be taken care of. We cover all which that implies by the term "stabilization." Of course there are no exact figures on it, but it is my guess, that of what we call the high-speed mileage in the United States, between 3 and 4 percent of it has these unstable spots.

Different methods have been employed down through the years to get rid of the water pockets or unstable spots or soft spots, as they are variously called. But as the speed of trains increases we have to do something about them. We must meet the need for tracks that will be safe for the greater speeds.

We are not responsible as individuals for the locations of any appreciable mileage of the tracks we maintain. If we had had a part in it, it is certain that, with the experience we have had in maintenance, we certainly would have put some of the lines in different places. But that does not alter the fact that much of the mileage contains soft spots.

The method that has been described here this morning is one of displacing water, and any method that will cure the bad spots in the roadbed at a reasonable cost will please the treasurer and also the investor, and we have to keep them both in mind.

I propose to do something on my railroad of a somewhat different nature. We have at one location almost 50 miles of line on an embankment only four to six feet high, substantially all of which is unstable. It is my thought that we might try to increase the density of the material in the embankment by compressing it with ordinary road rollers, putting them on each side of the track and just "ironing" the slopes up and down with them until we have compressed the material, so to speak. I am going to try it. If it hadn't been for the war, I would have tried it long before this.

As was said yesterday, sometimes we find ourselves in a blind alley and may have to back up, and other times we may have to admit failure. I hope this won't be a failure.

May I congratulate you and your committee, Mr. Swartout, on a most excellent and interesting report. You are doing a very, very good work. The committee is excused with the thanks of the Association.

Discussion on Ties

(For Report, see pp. 123–134.)

(President Miller presiding)

Chairman John Foley (Pennsylvania): There are no proposals for additions to the Manual. Aside from the revision of the Manual, all the reports are just for your information.

In the revision of the glossary we were governed by the instructions of the Committee on Manual to delete any items which were not referred to in Chapter 3 of the Manual.

In consequence, there were taken out numerous definitions relating to ties, but not of any particular interest to engineers, and there have been included some new definitions which I will not take the time to read unless any of you have read them and believe the definitions are not as accurate as they might be.

I move the adoption of these revisions of the glossary as well as the change on page 3–20 of the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Foley: The report on Assignment 4—Tie renewals and costs per mile of maintained track—is the customary annual compilation of statistics supplied by the Interstate Commerce Commission and compiled for use of the AREA by the Bureau of Railway Economics. There have been found some errors in compilation, and the necessary changes have been covered in this report.

It is hoped that all members will go back to their proceedings of earlier years and make the necessary changes. That report is submitted as information.

President Miller: And so accepted.

Chairman Foley: The next report, on Assignment 5, will be presented by Chairman Butler.

R. E. Butler (Newburgh & South Shore): This year's report on Cause and control of splitting in railroad ties will be found on page 126. It is devoted to a phase of the subject to which reference has been made in recent reports, that of preventing splitting before ties are inserted in track by the application of other than mechanical means, to resist the stresses of drying.

The statement regarding the vapor drying process is based on comprehensive reports of experimental and full-scale treatments at Spartanburg, S. C., submitted by the Taylor–Colquitt Company for study by your committee. In the preparation of the description of the operating procedure, M. S. Hudson, research chemist, collaborated.

In its Asheville division the Southern Railway has a section of track in which ties seasoned by the vapor drying process are being tested. The ties have been in track for more than two years, but because of travel restrictions your committee has not yet had an opportunity to inspect them. Pictures show these ties as free of splits as when installed. Their conditions after several years of service remains to be seen.

Experiments being carried on with other methods of artificially seasoning ties are engaging the attention of your committee, and it is hoped that our next report will provide data on such methods of drying ties.

This report is submitted as information with the recommendation that the subject be continued.

President Miller: It will be so received.

Chairman Foley: The report on Assignment 6 will be presented by Chairman Campbell.

F. G. Campbell (Elgin, Joliet & Eastern): Travel and working conditions during the two years this assignment has been under consideration prevented your subcommittee from meeting to discuss and prepare this report. However, all information received was sent to the members of the subcommittee and was the subject of comment by correspondence with the chairman.

The report presents the comprised views of the majority of the subcommittee but it does not represent complete unanimity of opinion. Statements which remain to be reconciled with the views of all members of the subcommittee are as follows:

> That the use of 36-in. joint bars, rather than 24-in. joint bars, will reduce mechanical wear.
>
> That ribs on the bottom of tie plates are of any benefit insofar as mechanical wear is concerned.
>
> That the use of screw spikes with double spring washers as anchor spikes will prevent movement of the plate on the tie.

It has been suggested also that the statement that certain types of mechanical wear will decrease as the size of the plate increases is too general and should be made specific by a recommendation as to the size of tie plate which should be used under varying weights of rail carrying varying densities of traffic.

It has been contended that the report overlooks certain very important items affecting mechanical wear of ties, such as the effect of proper tie spacing and the number of ties per rail; also the effect on the remaining sound ties of the deferred renewal of ties which have completely failed.

Although this report is submitted as information only, with the recommendation that the study be continued, discussion is especially invited.

Chairman Foley: The report on Assignment 7 will be presented by Chairman Turley.

C. D. Turley (Illinois Central): Assignment 7—Reasons for the removal of ties. When preservative treatment of wood first came to the attention of the railroads a number of experimental tests were established, primarily, to determine the economy of the use of treated wood, and also to facilitate the selection of the preservative and the method of treatment best suited in each particular case. Today, the economy in the use of treated wood is generally accepted but we find, in the case of cross ties,

that failures now occur from several causes other than decay. As a result, additional tests have been established to determine the causes which make it necessary to remove ties from track. Corrective action can then be taken to bring about improved service life. In order that any data now being compiled by the various railroads and by this committee will be uniform and comparable, this committee suggests that the statement form shown on page 133 be adopted and followed.

This report is presented as information.

President Miller: It will be so accepted.

Chairman Foley: That concludes the report of Committee 3.

President Miller: Mr. Foley, I cannot dismiss the Committee on Ties from the platform without appropriate recognition of the fact that with this appearance of the committee your term as its chairman is brought to a conclusion. Eleven years as chairman, following eleven years as vice-chairman is an extraordinary record of service to this Association, but in the light of your standing as an authority on ties, timber and wood preservation, it is not surprising that you have been asked to take a leading part in the work of this committee.

You have been a member of Committee 3 for more than a quarter of a century, and I hope that you will continue to participate in its work for many years to come.

The committee is now excused with the thanks of the Association.

Discussion on Wood Preservation

(For Report, see pp. 135-168.)

(Vice-President Akers presiding)

Chairman H. R. Duncan (Chicago, Burlington & Quincy): Eleven subjects were assigned to Committee 17, and we are reporting on three of them.

The subcommittees assigned subjects on which no reports are being presented this year have made considerable progress in the study of their assignments, but largely due to the unsettled conditions caused by the war, it was felt that this was not the opportune time to draw conclusions and present reports on these particular subjects.

Usually we have a very comprehensive report on subject 3—Destruction by marine organisms and possible ways of prevention. The work of this committee has been carried on under the direction of Dr. Clapp, since Colonel Atwood has no longer been active in this work, but Dr. Clapp has been quite seriously ill for several months. Consequently, we have no report on this subject. He is better now, and we anticipate that he will pick up where he left off.

Subject 1—Revision of Manual—will be presented by Mr. John Foley.

John Foley (Pennsylvania): This report on revision of the Manual is one which is largely governed by the policy adopted by the Committee on Manual and involves the deletion of quite a few terms which have been carried heretofore.

The conception of the committee regarding the glossary at that time provided definitions of almost every term that was used in wood preservation. Since the AREA Manual glossary is to contain only definitions of terms that are used in the Manual, a great many of these have to go out.

Reference to Chapter 17 in the Manual occurred in places where it did not belong and, in consequence, there have been suggested changes which involve the deletion of "17" and the inclusion of other chapter numbers, and we have provided all the chapter references that are involved.

Unless there is some question regarding any of these revised definitions, I will not read those on pages 136 and 137. I move that the material on pages 136 and 137 having to do with changes in the glossary be accepted.

(The motion was seconded, put to a vote and carried.)

Mr. Foley: On pages 17-3 and 4 of the Manual there was provision for the kind of material that should be used in requisitioning preservatively-treated wood. That list of suggested terms to be used in making such a requisition has been revised, but not to the extent of changing the original intention. It is merely a modernizing of something that was in the Manual for a good many years.

I move that the material on pages 137, 138 and 139 having to do with requisitioning of preservatively-treated wood be adopted.

(The motion was seconded, put to a vote and carried.)

Mr. Foley: It is proposed to delete from the Manual, in their entirety, all references to methods of test, since that is part of the policy adopted by the Board of Direction.

I therefore move that approval be given to the deletion of all references to methods of test in Chapter 17.

(The motion was seconded, put to a vote and carried.)

Mr. Foley: On page 140 there is a revision of the form for reporting the treating of wood which, to a slight extent, enlarges that which is in the Manual. It is recommended that the new form be adopted in place of the one which is now in the Manual. I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Foley: On page 141 there is another revision of a form which has been in the Manual. It does not change the nature of the information in any essential extent. It is recommended that the revised type of form be adopted instead of the one that is now in the Manual. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Duncan: The report, as stated by Mr. Foley, represents a tremendous amount of work, and I want to take this means of expressing my personal appreciation to Mr. Foley for the work that has been done.

Subject 2—Service test records of treated wood—is a continuation of the usual service test report we make each year, and it has been printed. We won't have any detailed remarks on it. It is offered as information.

Vice-President Akers: It is so received.

Chairman Duncan: Subject 5—Destruction by termites and possible ways of prevention—will be presented by Dr. Hermann von Schrenk.

Hermann von Schrenk (St. Louis, Mo.): This report is a continuation of the installations which were established some 12 years ago, and one part of which was completed about six years ago. At that time it was felt that one of the difficulties which the railroads encountered in connection with this termite problem was to know what compounds should be used or might be used, both for permanent prevention as well as for emergency purposes.

After some considerable discussion your committee decided to test the compounds which were offered commercially by various manufacturers and which we felt offered some reasonable prospect of giving effective protection.

The compounds which were tested are listed on page 146. In presenting this report we would like to emphasize what is stated in the report, that neither the committee nor the Association were in any way committed to the endorsement or otherwise of any of these compounds. We undertook to test them, with a statement of the results from time to time, without, as I say, any obligation whatsoever.

There is one item to which attention has been called, which we were advised might be subject to misunderstanding. The conclusions on page 168 we thought indicated

very clearly that the analysis of the failures or successes was to be applied only for the period covered by the report, namely a five-year service period. However, the critic who made this comment believed it wasn't strong enough, so the committee presents an addition to the conclusions on the page just referred to, which we would like to have appended to the report of the committee.

In the second paragraph of the conclusions, the committee states "The chemical compounds and methods of their application to the posts which to date have entirely prevented attack by termites as well as decay were:" It is suggested that this sentence should be reworded so as to include quantities of compounds so it will read "The chemical compounds, the quantities of such chemicals retained and methods of their application to posts which to date have entirely prevented attack by termites as well as decay were:"

While the committee believes that the conclusions do not in any way imply any recommendations, either as to chemicals used, the quantities retained or the process used, in view of the criticism made since the report was printed, we again wish to state very specifically that this is a progress report and that the results given in this report apply only to the period of testing, which means a five-year period. What will happen in the future, the committee of course is unable to predict.

It will not be necessary to go into the details of the report. If we ever make another inspection, this committee would welcome the volunteer cooperation of any member of this Association who wants to come to Florissant and help dig up the posts and look at them. This report, as you look at the 26 pages, gives you an indication of the enormous amount of work that was involved and the care which the committee took in order to make impossible any misinterpretation or any loss or error in this particular test.

The results have been really rather encouraging because they indicate we were probably correct in our assumption when we started these tests, that we could get up some kind of a plan whereby any railroad officer could go to any commercial house and purchase the chemicals directly which give indications of good risk and would materially aid in the preventive measures undertaken.

As I think I stated before from this platform, the country is now rife with termitologists who are trying to get people to do certain things with their compounds and their methods.

What we tried to do in this series was to give a clear indication of possible risk of application of the various compounds which had the greatest probability.

I think the report speaks for itself, and it is presented as information.

Vice-President Akers: It is so received.

Chairman Duncan: That completes the report.

Vice-President Akers: The Committee on Wood Preservation has just presented another valuable and informative report. I can say personally that the work of this committee has been of enormous benefit to my own railroad. I would like to express to these gentlemen my personal appreciation as well as that of the Association.

However, before excusing you, Mr. Duncan, I wish to thank you personally for your valuable service to the Association during your term as chairman, which terminates at this time. The committee is excused with the thanks of this Association. (Applause)

Discussion on Waterways and Harbors

(For Report, see pp. 105–112.)

(Vice-President Akers presiding)

Chairman Benjamin Elkind (Erie): We had six subjects assigned and are offering reports on two of them. A correction should be made on page 105 under subject 4. Instead of "Final report, presented as information" it should read "Progress report, presented as information."

A report on Assignment 3 will be offered by Mr. P. T. Simons of the Missouri Pacific.

P. T. Simons (Missouri Pacific): The subject is Prepare abstract of the Truman–Hobbs Act and outline procedure under the act. This is quite a job. The report is merely an outline of the procedure. It is divided into two subjects: one is legislation and the other is procedure.

Under legislation we have mentioned four items which I will not read, but which outline in a general way what the subject comprises.

Under procedure there are eight items and these, likewise, I will not read, but I will say that these eight items outline in a general way what the procedure is.

This subject and these outlines comprise a final report, which is presented as information. There is a lot in this report for anyone who wants to work with it.

Chairman Elkind: The report on Assignment 4 will be presented by Mr. W. D. Faucette.

W. D. Faucette (Seaboard Air Line): Page 105 states that this assignment which reads "Reasonable life of steel casings immersed in sea water" is a final report. This is not a final report and it cannot be for some time.

I confess to you I have been at times a little in a state of surprise as to how "reasonable life of steel casings immersed in sea water" became a part of the assignments to this committee, but as it was assigned to us, I am gladly reporting on it.

During the war, tests and research in this matter were almost entirely suspended. We have been making contact with the War Department whom we knew were making inquiries in regard to this subject. This committee has not been able to do much initial work on it, but we have availed ourselves of the data that were put in our custody and for which we give appreciation and hearty thanks.

On the question of the Carnegie–Illinois Steel Corporation work (Mr. Larrabee), I invite your attention to page 108. I will not read any of this because it is rather heavy going, and I recommend it to your reading if you are interested in this subject of the life of steel casings. On page 109 we have a summary of the work Mr. Larrabee did, and I am sure if you will write to the Electrochemical Society of New York you will get more extended data.

Dr. Clapp, in the corrosion course of Stevens Institute of Technology, wrote an article on "The Effect of Macro-Organisms on Metals in Sea Water." While it is not as comprehensive as the assignment we have, it is very interesting, and we obtained Dr. Clapp's consent to use what we have reproduced here.

It is our hope in the next 12 months we will be able to get from other sources than the War Department further data that would add to the record that we have endeavored to make in this investigation.

I would like to ask if any of the members of the Association who are interested in this question of reasonable life of casings immersed in sea water, have any data that would be of value to the Association and to the engineering profession as a whole, that they be kind enough to send them to us.

This is submitted for whatever educational benefits it might give you.

Chairman Elkind: This concludes the report of the Committee on Waterways and Harbors.

Vice-President Akers: Thank you very much, Mr. Elkind, for the excellent presentation you have made.

The committee is now excused with the thanks and appreciation of the Association. (Applause)

Discussion on Rail

(For Report, see pp. 365–480.)

(President Miller presiding)

President Miller: We will now receive the report of Committee 4—Rail. The chairman of this committee is Mr. W. H. Penfield who retired from his position as chief engineer of the Chicago, Milwaukee, St. Paul & Pacific on November 15, 1945. In his absence the report of the Committee on Rail will be presented by the vice-chairman, Mr. C. B. Bronson, who will succeed Mr. Penfield as chairman at the close of this convention. I am sorry indeed that Mr. Penfield is not here because it denies me the privilege of offering some expression, on behalf of the Association of our appreciation of his valuable service as a member, vice-chairman and finally as chairman of the Committee on Rail. Mr. Penfield did a magnificent job.

Vice-Chairman C. B. Bronson (New York Central): As our president has told us, Mr. Penfield is not with us today. So the mantle falls on me to present the report today. I will do the best I can in his absence.

It is with deep sorrow and regret that we record here that a dear friend, member and colleague, B. R. Kulp, passed away. In our meeting of the Rail committee yesterday we drew up a resolution which I would like to have incorporated in the minutes of the convention.

Burr Robert Kulp

Burr Robert Kulp, chief engineer of the Chicago & North Western Railway, died at his home in Evanston, Ill., on February 27, 1946.

He served for ten years as a member of Committee 4—Rail, and at his death was chairman of Subcommittee 13. Because of his professional attainments, as well as for his personal qualities, Mr. Kulp was a highly esteemed member of this committee.

We take this opportunity to record the loss suffered in the death of Burr Robert Kulp.

The Committee on Rail

The first official business of the Rail committee is that on revision of the Manual. It covers a number of items the first one of which is the question of definitions. We made a very thorough study of everything that the Rail committee was responsible for in the way of definitions in the Manual, and we are offering four things: Minor revisions, major revisions, new definitions and deletion of terms. They have been in the hands of all members of the Association for some time and it isn't necessary to read these in detail.

I would like to make a motion that the minor and major revisions and the new terms and deletions be substituted or incorporated in the Manual.

(The motion was seconded.)

C. R. Strattman (New York Central): I notice you have compromise joint there but nothing about compromise rail. Has it been decided to eliminate the compromise rail?

Vice-Chairman Bronson: Not necessarily. Possibly it is one term that was overlooked.

I. H. Schram (Erie): If it is desired, we can handle it in the Track committee and leave this report stand, because compromise rail is really an adjunct to frogs, crossings, or other fixtures, which really come under the jurisdiction of the Track committee.

If it is agreeable with you, Mr. Chairman, I can handle it in that way.

President Miller: That is a way of handling it that I think is entirely proper.

(Vice-Chairman Bronson's motion was then put to a vote and carried.)

Vice-Chairman Bronson: The next item is minor revisions of forms and figures. This is a matter of editing, not anything of great importance but in order to bring the Manual into proper condition and form, we are recommending, and I make a motion to that effect, that the minor revisions of forms and figures be incorporated in the Manual.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Bronson: The next item is recommended practice for rail inspection. In reviewing this subject critically, we found that because a large number of roads are availing themselves of commercial rail inspection and there are deviations in practice from one road to another, it seemed it was no longer essential.

We therefore recommend the elimination of the recommended practice for rail inspection from the Manual, and I so move.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Bronson: The next item is Specifications for Heat-Treated Carbon Steel and Alloy-Steel Track Bolts. The only change made and recommended, and it is a very important one, is the introduction of two types of fits, that is, for the so-called free fit (Class 2) and wrench turn fit. These were largely used during the emergency and proved satisfactory, and we decided it would be highly essential to incorporate them in the present specification.

I therefore make a motion that the changes indicated on page 372 be incorporated in the Manual and substituted for the present Section 13.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Bronson: The next is the girder rail section specification. The use of the girder rail is very limited in this country, as far as the steam railroad is concerned. The material on this subject takes up considerable space in the Manual. Accordingly it seems no longer necessary to continue this as subject matter in the Manual, because it is readily available through the American Transit Engineering Association.

I therefore make a motion that the Specifications for Open-Hearth Steel Girder Rails of Plain, Grooved, and Guard Types, and the rail sections be eliminated from the Manual.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Bronson: The most important new item we have is that covering specifications for open-hearth steel rails. Up to the present time the control cooled feature has not appeared as an integral part of the specification, although it is largely if not almost universally used.

We had some important meetings with the manufacturers. We ironed out a few differences, and we finally arrived at what we consider is a very workable specification, in which control cooling is specifically covered. Of course, there are certain features that some roads might consider supplemental or necessary beyond what is

shown in the specification here but from the standpoint of the Association it seemed we covered this thoroughly enough so that we have a real, workable specification.

I therefore make a motion that the Specifications For Open-Hearth Steel Rails, as shown on pages 372–378, be substituted for the present open-hearth steel rail specification in the Manual.

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Bronson: That completes the work of Subcommittee 1 on revision of Manual.

The next one is rail failure statistics, which is Assignment 3 and will be presented by Mr. W. C. Barnes. There are three outstanding points in connection with this. One is the indication that we have apparently reached the peak of fissured rails and are on the downhill; we hope so, anyway. The second one is, you notice on one of the charts the almost universal use now of control cooled rail. The third feature is the marvelous record we are obtaining from control cooled rail from the standpoint of fissures and, incidentally, from head failures.

While the number that are indicated in the report appear to be considerable, they are very much lower in proportion than we have ever had before. Mr. Barnes will present the report.

W. C. Barnes (AAR): These rail failure statistics for the year ending December 31, 1944, have been prepared in the form which was initiated in the report presented last year, which gives special emphasis to the performance of control cooled rail. Sufficient data are presented covering rail made by all processes, to provide a continuing record and afford a basis of comparison with the rail made by the control cooled process.

Table 1 shows separately the service and detected transverse fissured rails reported each year by each reporting road. These data cover reports on 44,273.96 track miles of rail of all ages and made by all processes. The total service failures for all roads in 1945 were 6927, and detected failures 31,781. Those were reported transverse fissure failures.

It will be noted that the 1945 service failures were less than those reported for 1943 and 1944, and it is possible that the intensive detector car testing of recent years and the increasing proportion of control cooled rail in track, as indicated in Fig. 3, are responsible for this improvement.

The effect of the use of control cooled rail is made clear by confining our comparison to the failures reported in rails rolled within the last ten years, during which period control cooled rail was adopted. During this ten-year period, 33,592 track miles of control cooled rail produced only 32 transverse fissures from all causes or at the rate of 0.03 per 100 track mile years, while 9520 track miles of rail made by other processes, exclusive of Brunorized rail, produced 13,413 transverse fissures, which is at the rate of 18.30 per 100 track mile years. In other words, the other processed rails produced 610 times the number of transverse fissures per 100 track mile years as did the control cooled rail.

Table 3 shows a marked decrease in accumulated failures of all types in 1937 rail, when control cooled tonnages started to predominate, as shown in Fig. 3, as compared with earlier rollings. The footnote on Table 5 shows that porosities in the steel were the major cause of the few transverse fissures reported in control cooled rail. Steps are now being taken by the mills to overcome that difficulty.

I would explain that the total fissure failures reported in Table 6 are accumulated to September 1945, while those in Table 5 are to December 1944. Other tables and figures are fully explained in the text.

Vice-Chairman Bronson: The next report—Continuous welding of rail—will be presented by Mr. Schram.

I. H. Schram (Erie): The information that is presented here is for information only. We have kept a record of the installations originally selected for test and the failures reported. Those data are on the first inset table. The additional locations and similar data are indicated on the second inset table, and on page 393 are given two summary tables showing the data to date, with the number of failures. We are simply presenting this as information to indicate what is happening on these stretches. We are not yet ready to draw conclusions. The data are submitted for information only.

President Miller: They will be so accepted.

Vice-Chairman Bronson: The next two reports are along the same line, which are: Investigate joint bar failures and give consideration to the revision of design and specifications, and service tests of the various types of joint bars.

In the absence of Mr. Ray McBrian, the report will be presented by Mr. Magee. There is also a supplemental or fourth progress report of the rolling-load tests of joint bars which Professor Alleman will present.

G. M. Magee (AAR): In 1937, 9 installations of various designs of joint bars for 112-lb. RE rail were installed on the Santa Fe Railway near Streator, Ill. In the same year 12 half-mile test sections of different design of joint bars were installed on the Pensylvania Railroad near Valparaiso, Ind.

Since that time yearly measurements have been made of various characteristics of the performance of these joints that were considered to be indicative of the efficiency of the performance in track.

The report gives diagrams showing the essential features, including comparisons obtained in these different measurements. After eight years' service—in fact, it is almost nine years now—and the test tracks having carried a heavy traffic tonnage through that period, the amount of wear has progressed on these bars so that we were able this year to offer some fairly definite comparative ratings.

In Table 5 is given a rating performance judged on the basis of the test measurements of the various designs of joint bars. I won't go into that table in detail except to point out the final ratings given in the last column. Those marked with A were considered to be giving the best performance and those of lower letters the next best.

One of the most interesting results obtained in these tests was the good performance shown by end-hardened rail and, rather surprisingly, not only was the batter in the end-hardened rail less but the joint bars themselves have shown less wear and a much better tendency to support the joints on the end-hardened rail than on the unhardened rail.

Another important conclusion is on the length of the joint bars, the 36-in. joint bars giving longer life and better performance than the 24-in. No outstanding difference has been noted in performance between the head contact or headfree design bar on the angle bar type.

That concludes the remarks I have to make on Assignment 7. The report is offered as information.

President Miller: It will be so received.

Mr. Magee: Assignment 8 is a study of joint bar failures, having particular emphasis placed upon the material or metallurgy of the bars. A brief report is given on a test that has been under way for several years on the Burlington Railroad, including joint bars of various metallurgies. No definite conclusions have been indicated

by the test measurements to date, the service performance not having been long enough as yet.

The major part of the work on this assignment is consisting of rolling-load tests of joint bars, conducted in the rolling-load machines at the University of Illinois. Professor N. J. Alleman on the University staff, who has been in charge of these tests, will discuss the results that have been obtained.

N. J. Alleman (University of Illinois): In the rolling-load test of the past year, the main attempt has been to ascertain the effect of joint bar life with different types of chemistry.

The tests during the past year have been confined to the 112 K2 headfree bar with top central overfill and easement. This bar was chosen because we could get it with the AREA chemistry, and two other chemistries of shell steel, both 0.55 carbon, one with 0.84 manganese and the second was 0.98 manganese.

Seventeen tests were made; 9 tests on the hot-sawed rail and 8 tests with cold-sawed rail ends.

Although we attempted to eliminate the hardness variable in these tests by taking Brinell hardnesses on each bar before testing, the Brinell hardness varied from 216 to 292. That is a variable that enters into our test and tends to confusion, in that it obscures the effects of variation in chemistry.

In comparing the shell steel bars with cold-sawed rail ends, the cyclic life with beveled ends was about twice that with unbeveled ends for bars of like hardness, and the shell steel bars indicate that bars in the hardness range of 250 to 280 are rather notch sensitive.

For the first two years, covered in the first two reports, we encountered some bars of very low Brinell hardness. We then made an attempt to get bars of higher Brinell hardness. After we got the bars of higher hardness, we found that another variable enters the picture, in that the bars of higher Brinell hardness are rather notch sensitive.

Our observations from the 17 tests reported are as follows:

1. The mill-formed, hot-pressed easement on headfree bars reduces but does not eliminate gouging by the rail ends.

2. An examination of bars after testing reveals transverse cracks on the top surfaces in the vicinity of the rail ends.

That is true for all tests. No matter where the bar broke, top surface or bottom surface. If we ground off the gouge on the bars, we found top surface cracks caused by gouging of the rail ends.

Our conclusions of the 17 tests are:

1. Hot sawing of rail ends distorts the rail fishing surface, reducing the fishing height in the vicinity of the rail end.

2. The condition of the rail end, whether hot or cold sawed, or beveled, has an appreciable influence on the fatigue life of joint bars.

3. The tests indicate that shell steel and high manganese bars are satisfactory if the Brinell values are not too high.

These tests were made in an attempt to find a better design of joint bar. Coming out of the tests, we find, first, a variation in Brinell hardness which tends to hide the cyclic life of bars. Along with that, we find that lack of beveling or the notch effect of the rail end is a very serious problem affecting the cyclic life of the bars. When we consider beveling of rail ends one tends to think of the beveling of the top surface, but the beveling of the fishing surface at the end of the rail, when we think about the bar, is very important.

For the past year we have had one machine. Now we have two new machines installed, and we expect our joint bar test to make more rapid progress.

For the coming year we plan to test 131-lb. rails and bars, covering the AREA bar, K14 and one type of angle bar. We are also making tests on TR rails and bars.

Vice-Chairman Bronson: The report of Subcommittee 8 including the appendix Professor Alleman just presented is offered as information.

President Miller: It will be so received.

Vice-Chairman Bronson: The next subject is: Corrugated rail—causes and remedy. Mr. Johnson of the Illinois Central is chairman but in view of the fact that the entire work was done by Professor Cramer of the University of Illinois, we decided it would be better for him to present the report. I will therefore call on Professor Cramer.

R. E. Cramer (University of Illinois): This is a preliminary report only. It is brief. I will read a few of the statements as printed in here.

(See pages 427–430.)

Professor Cramer: This was done as an experiment, to show that the corrugations are hard spots. We think this is a new conception of the nature of corrugations that has not been recognized by all railroad engineers.

If you want to test these rails in track, either hard streaks or intermittent hard spots called corrugation, take a three-cornered file and make one scratch across a spot. You will find the bright spots much harder than ordinary rails. We think that grinding these off the hard spots is the best way of getting rid of them. You don't have to take the rails out of the track, just get rid of the thin hard spots either by grinding or flame tempering, and the rail should be as good as it was before.

The writer does not mean to contend that all types of corrugation are the results of hard spots caused by wheel slippage. There probably are other service conditions which can cause a rail to become rough, and it is believed this is particularly true of rails in sharp curves which develop relatively long corrugations.

Vice-Chairman Bronson: The report of Subcommittee 9 is offered as information.

President Miller: It will be so received.

Vice-Chairman Bronson: Assignment 10—Development and characteristics of fractures under engine burns in rail. Mr. J. B. Akers, chairman.

J. B. Akers (Southern Railway): This deals with the development and characteristics of fractures under engine burns in rail. This report is offered as information, with the recommendation that it can be continued.

Work has been in progress, but has been delayed by breakdowns of the rolling-load machines. The procuring of repair parts has been difficult. An appropriation of $1000 was authorized for 1945, and an appropriation of $11,000 has been approved for 1946. This money is to be used for the purchase of one or possibly two additional rolling-load machines or units of better design and, also, for the employment of an attendant, and for other expenses.

So far we have tested 29 rails in the rolling-load machines, and for simplicity we will consider those in four groups.

(He read the first four paragraphs on page 431.)

Mr. Akers: The testing at the research laboratory of the Metal & Thermit Corporation is intended primarily to determine the growth of fracture under engine burns. The size of the fracture at the beginning of the rolling-load test was determined by the Sperry hand-testing method at the laboratory of the Sperry Company. Additional measurements were made by Sperry after each 75,000 cycles. In six rails so tested, there was a pronounced increase in the size of the fracture up to failure, and

all of the failures occurred in less than 357,000 cycles, and with three of the failures in less than 94,000 cycles. That is further indication of the danger of an engine-burned rail which has a fracture beneath.

No conclusion can yet be drawn from any of this work but in general it appears that: (1) A rail containing an engine burn from which a detail fracture has started is likely to fail and should be removed promptly from track; (2) the welding of engine burns apparently results in some improvement of the condition, and rails containing burns that have been welded may be expected to give reasonably good service.

Vice-Chairman Bronson: This report is presented as information.

President Miller: It will be so received.

Vice-Chairman Bronson: Assignment 11—Investigate causes of shelly spots and head checks in rail surfaces for the purpose of developing measures for their prevention. Mr. F. S. Hewes will present the various features of that report.

F. S. Hewes (Atchison, Topeka & Santa Fe): This year's report is offered as information. This is our fourth annual report on this assignment. We have not yet found a solution to our problem, but the most promising developments so far appear to be the 3 percent chrome steel and the modified head contours. Our field tests of many kinds have not been in service long enough to furnish definite conclusions at this time.

This report is divided into three main parts. Group 1 is handled directly by the subcommittee. We have about exhausted our study of items (a) to (e), inclusive, and are concentrating on items (f) and (g).

Group 2 is handled by Mr. Magee and Mr. Cress and others of the Engineering Division research staff. This year's study has been confined mostly to items (c) and (d). Appendix 11-a covers this part of our report.

Group 3 is handled by the University of Illinois staff under Professor Cramer. They are still actively engaged, principally in items (b), (c) and (d). Appendix 11-b covers this part of our report.

Appendix 11-a begins on page 435. During the past year extensive stress measurements were made on 131-lb. RE rail in tangent track and a 6-deg. curve on the Norfolk & Western Railway under actual traffic conditions. The westbound track on this curve carries heavy coal traffic, in 55, 70 and 90-ton cars. The outer rails formerly in this curve developed very severe shelling.

The eastbound track at this location was also tested. This curve, carrying the empty coal cars, was not troubled by shelling. No significant differences were found between the maximum stresses obtained on the westbound and eastbound outer rails of this curve that could explain the shelling on the former and not on the latter. The stresses were higher under the loaded cars than under the empties, but the stresses under the loaded coal cars were only about one-half as great as under the locomotives. Further study is necessary on this feature.

The remainder of Appendix 11-a covers tests made at the same rail lengths and made at the same time as those just described, covering the internal strains developed by traffic at the gage corner of new rail and used rail and also covering dynamic stresses at the end of used rail.

The conclusions to date of these measurements at the joint gap of rails are presented on pages 442 and 443.

Appendix 11-b begins on page 443. Professor Cramer during the past year has continued the studies and rolling-load tests at the University of Illinois. He studied the physical properties of some rails, using these tests, and finds that the 3 percent chromium rail has high hardness values and high endurance limits.

He has also continued his rolling-load tests, not only with the cradle machine holding a full section rail specimen, but also with the rolling-load machine to test the rail specimen with the head machined to provide a 1-in. wheel path.

These tests indicate the superiority of the 3 percent chromium rail and give some hope that a heat-treated rail may be developed to resist shelling in actual service. Several low alloy steels and some heat-treated alloy rails are being tested at this time but the results are not yet available.

Professor Cramer is periodically inspecting and measuring the hardness of standard rails laid in 1943 on four curves on the Chesapeake & Ohio. This same procedure is also being followed for the 3 percent chromium rails on the Norfolk & Western.

This report is offered as information, with the recommendation that the subject be continued.

President Miller: It will be so received.

Vice-Chairman Bronson: Assignment 12—Investigate recent developments affecting rail design. I happen to be chairman of that subcommittee. The work has been done largely by Mr. Magee and his staff, also in cooperation with the rails investigation at the University of Illinois.

We might be criticized for the fact that although another year has passed, we have offered no modifications of rail design to the Association but, without any reflection on past methods of rail design or methods of developing rail designs, this is really the first time that a highly scientific method is being utilized to determine the actual stresses in rail and from which deductions leading to possible improvement could be made. That is because we now have very delicate gages with which the entire rail section can be surveyed.

I think I can confidently predict that we will be in position to offer what changes seem essential in the two principal sections, that is 112 and 131, so that they will be available for the placing of orders by railroads so desiring, for the 1947 requirements.

I would like to call on Mr. Magee to present the report.

Mr. Magee: The principal consideration in the studies that we have been giving to rail design has been with reference to the fillet stresses. In connection with some measurements made in track a few years ago, it was made clear that surprisingly high stresses were developed in the upper part of the rail web and in the upper rail fillet as a result of occasional eccentric loading of the rail.

As you know, the wheel tread becomes worn to a hollow contour. There is considerable lateral play between the wheel gage and the rail gage and, in the course of a train pasasge, occasionally a wheel will run over so the flange is in contact with the gage corner of the rail. This places practically a concentrated loading right on the gage corner, tends to bend the rail in and downward and produces a high compressive stress in the upper fillet and the upper part of the web on the gage side.

Occasionally another wheel may do just the reverse and bear on the field side of the rail. This tends to develop a tensile stress on the gage fillet and the upper part of the web. So we have, with this varied condition of wheel bearing, a range of stress variations which is conducive to producing fatigue failures.

We have gone into the investigation very thoroughly. Extensive field measurements have been made on tangent track and curved track to determine the range of stresses that occur in service.

In addition, at the University of Illinois fatigue tests were made of steel taken from the webs of rails with the mill surface left on, and subjected to the same range of high compression to low tension to which the steel is subjected in service. From these tests, the fatigue strength of the steel was determined.

Using these data, together with the range of stress actually found in service, we have experimented with study designs of rail until we have found designs for the 112 and 131 sizes which will bring those stresses in the upper fillets and upper rail web down to where, except for very unusual conditions, they will be well within the strength of the rail steel.

I would like to call attention, just for a moment, since we do not have any slides of this, to the 112 RE section which is shown on page 454. There are four stress lines shown for four different cases of eccentric loading. The one farthest to the left is for the 40,000-lb. load, ¾ in. eccentric on the gage side. Note the peak stress that occurs in the fillet. With this loading, this localized compression has a value of approximately 37,000 lb. per sq. in. Directly across is the study section H rail. The upper part of the web has been thickened and a larger fillet radius is introduced. You will note that this localized stress in the fillet has been reduced down to a value of 27,000 lb. per sq. in., a very material reduction, with a slight additional amount of metal.

One other fact that I would like to point out, which we have discovered more or less inadvertently in these tests and which I think should be well understood, is shown on page 459 where a vertical wheel load of 40,000 lb. is combined with a lateral load of 10,000 lb.

These tests were made on both flat and rolled crown rail seat tie plates. It was found that the stresses in the upper part of the rail web and fillets were not affected to any appreciable extent by the addition of the lateral load. However, the lateral load did tend to produce high stresses in the lower part of the web and the lower fillets opposite the gage side. Of particular interest over the rolled crown tie plate is the high tensile stress produced at what is marked gage 19. That is a tensile stress parallel to the length of the rail on top of the outer edge of the rail base, directly over the point of bearing with the rolled crown plate.

If you will note the tensile stresses shown, there is an increase from the value of 30,000 lb. per sq. in. tension over the flat seated tie plate to almost double—as much as 50,000 to 55,000 lb. per sq. in.—over the rolled crown tie plate.

It is a fact that there has not been very much rail breakage, so far as we know, due to the use of rolled crown plates, but from an engineering standpoint this design of plate has introduced a factor in rail stresses which should be widely understood and recognized.

The report is presented as information. As Mr. Bronson said, our work on the design of these sections has been practically completed, and it is expected that designs will be available for consideration within the next few months, at the latest.

President Miller: The report will be received as information.

Vice-Chairman Bronson: The concluding portion of the Rail Committee's report covers the Twelfth Progress Report of the Joint Investigation of Failures in Railroad Rails in Service and Their Prevention.

Right here I would like to state that we have had splendid cooperation of the rail manufacturers and the American Iron and Steel Institute. They have been very helpful to us in the studies and in the solution of our problems, offered us excellent advice, guided us in connection with our specifications, and have contributed liberally to the studies in connection with rail failures and rail difficulties. They have also taken a very active, personal interest, by attending sessions out in the field and in joining in the investigation in a very fine way.

One of the highlights of the last eight or ten presentations of the report of the Rail committee, was the address made by Professor H. F. Moore, who was in charge

of the rails investigation. Professor Moore has retired, but it is indeed very fortunate that a brilliant young man has been appointed to carry on that work. That young man is Professor Cramer, and he will now present the twelfth progress report.

R. E. Cramer (University of Illinois): I will make this very brief and go back and cover a few of the other things we have been working on beside the transverse fissure work.

The staff of the rails investigation now consists of three engineers, Professor Alleman, Russell Jensen and myself, and three mechanics. This is compared to the old days when we had about seven engineers and seven mechanics working under Professor Moore.

We are now doing some work for six of the subcommittees of the rail committee, and just recently offered to work on a small job for the Track committee. We enjoy having a variety of subjects and different kinds of steel to work with.

The work of the rails investigation during the past year is presented in four subcommittee reports. The first is under Assignment 9—Causes and remedy for corrugated rails.

Several specimens of corrugated rails were sent to the university laboratory for study. These rails have all shown the same characteristics, that is, the bright or high spots of the corrugations are hard spots consisting of martensite produced from the heat of wheel slippage. Metallographic studies have shown that the hard surface layer varies in thickness from one to five thousandths of an inch.

(Two slides were described at this point.)

The second part of our work is covered under Assignment 11—Investigate causes of shelly spots. This work consisted mostly of rolling-load tests in our cradle type machine. We developed that two or three years ago. A number of men contributed to it, and it is a real rail beater. It will fail rail in two weeks, even the best, and gives us quick information on the relative resistance of rails to failure.

(Results of tests with this machine were shown on slides.)

To summarize our observations on shelling: It looks as if a heat treated low alloy steel would be the cheapest for the job. Three-percent chrome was good, but it is hard to make and it is expensive. A mixture of alloys, either enough to bring the hardness up to around 350 or lower, treated to 350 or above, is the best thing we found so far. We are still making tests. We have ten more samples to test, and we may find something better.

The third part of our investigation has been carried out by Russell Jensen for Subcommittee 12 on Rail Design. These are compression fatigue tests. The type of specimen used is shown on page 464. The surface of these specimens which receives maximum compression is the original surface of rail webs. Tests were made using specimens with stamped numbers and without numbers. The specimens without numbers have a fatigue strength of about 59,000 lb. per sq. in., and those with numbers, not taking out the cross section which is stamped out, have a strength of 51,000 lb. per sq. in.

We are going to make more tests, including some which have been corroded, as happens in track, and some treated in different ways.

The last part of our work is the Twelfth Progress Report on the Cooperative Investigation of Rail Failures in Service. This year we are submitting a final report on the Service Tests of End-Hardened Rails on the Chesapeake & Ohio Railway at Carey, Ohio. This test was started, I believe, in 1939.

The unhardened rails show considerable batter all the way through. We have some groups which do much better. The following conclusions have been drawn from these tests.

There is a decided reduction in the end batter of end-hardened rails compared to those not end-hardened. That is also borne out by those tests on the Santa Fe and Pennsylvania, carried on by Mr. Magee and his staff.

Rails quenched with water developed many weeping cracks while very few developed in air quenched or self-quenched rails. The quenching effect of water is just too severe, and the sooner we stop it, the better. It has been stopped by all the mills. I think some of the railroads are still using the old sprinkling, hand method. The best material is compressed air. You can't over-harden the rail. You do it every time with water.

The average hardness of the rails in the three groups quenched with compressed air which have not required welding up of the rail ends was in the range of 361 to 374 Brinell numbers. That was after some traffic. It might have been found a little softer than that if we had taken measurements right at first, especially if we had not ground out the carbon on the surface; 350 to 400 is a pretty good hardness.

The fourth conclusion is that rail ends made too hard and then rehardened to a lower hardness, developed many weeping cracks on the end. That method, which was applied accidentally, is not a success.

A proposed list of recommendations for end-hardening of rails is given, based on the results of the service tests of the Carey test track.

The last part of the Twelfth Progress Report gives the results of laboratory examinations of 25 rails which failed in service, most of which were originally classified as transverse fissures by the track men. We received about thirteen a year for the last three years, and that doesn't represent more than about one rail in a million. Of course, they happened to be from a couple of mills that have had most of this trouble so that makes it, for those mills, higher than that, but they are aware of it. They know just what is causing it, and now that the war is over, I think they will put in equipment that will prevent it. You don't have to take out heats on account of this. Even if you get two out of the same heat it is a matter of accident. It doesn't have anything to do with control cooling; it is caused by the heating process.

Three of the failures sent to us were transverse fissures from shatter cracks in rails made in the first year, but why that happens is well known. It only happened in one mill, and the cause was corrected in 1937. From 1937 on no control cooled rail has produced a transverse fissure from shatter cracks. I think that is a remarkable record. The remainder of the failures were wrongly classified as transverse fissures, being detail fractures from shelly spots and other types of failure.

I have already mentioned that these 15 failures from internal defects in the rails represent only about one failure per million control cooled rails now in service, and we think the rail mills should be given full credit for such a low transverse fissure record in control cooled rails.

In conclusion, I would like to say, we are always available for consultation and, especially, we want information as to what is happening on your railroad. Write us a letter. In fact, you are supposed to send us all the control cooled rails that develop a failure which looks like a transverse fissure. Maybe we will find something new once in awhile. If you have the opportunity, come down and visit us. We would like to talk over our problems with you.

Vice-Chairman Bronson: That concludes the report of the Rail committee. While it has been rather time-consuming and covered a wide field and scope, we feel that

the subject really warranted it, and that it is of great value to the Association and to the members individually.

President Miller: Mr. Bronson, your committee is carrying on some exceedingly important work; it always has and it probably always will. I want to congratulate you and your committee on the splendid report of today. The reports of this committee are always full of substance. The committee is now excused with the thanks of the Association.

Discussion on Track

(For Report, see pp. 481-545.)

(Vice-President Akers presiding)

Chairman I. H. Schram (Erie): The report of Committee 5—Track will be found on page 481. There is also some information that was printed in advance and will be found in Bulletin 453, (pages 48 and 65). That was a description of some of the research work that had previously been completed and was printed at that time as information. If there are no comments on the data in Bulletin 453, we will ask to have it accepted as information only.

Vice-President Akers: It is so accepted.

Chairman Schram: The first report of the Track committee will be that on revision of the Manual, which will be presented by Mr. Strattman.

C. R. Strattman (New York Central): The first part of this report will be reported later by Subcommittee 6—Tie Plates.

(He then submitted the revisions presented on pages 482 and 483, regarding matter on Manual pages 5–18, 5–49 and 5–54.1, and his motions for their adoption were passed. He then read the recommendations for revisions of or additions to the glossary in the Manual.)

Mr. Strattman: These are just minor changes of material in the Manual but the idea is to get them the same in the Manual as they are in the glossary of the Trackwork Plans. I move the adoption of all these revisions.

(The motion was seconded.)

Vice-President Akers: This morning someone asked about a definition for "compromise rail," when the matter of "compromise joint" was brought up. I wonder if that will settle the inquiry.

Chairman Schram: There is a complete definition for each of them, and the term "compromise rail" is most used in connection with turnouts and crossing problems.

(Mr. Strattman's motion was then put to a vote and carried.)

Chairman Schram: The second subject of the Track Committee—Fastenings for continuous welded rail, collaborating with Committee 4—Rail: On this subject we have no report this year, except to say that the tests being made on the New Haven are being continued and are being studied. They were described in the Proceedings of last year. There is nothing that we wish to add at this time.

The next report will be that of Subcommittee 3— Plans and specifications for track tools. That will be submitted by Mr. Cornell, chairman of the subcommittee.

W. E. Cornell (New York, Chicago & St. Louis). Your committee submits for adoption and publication in the Manual combined specifications for ash and hickory handles. It is the opinion that there is a definite need for ash handle specifications and that the combining of such specifications with the present hickory handle specifications has been accomplished with full clarity and with considerable saving in Manual space.

Since considerable of the subject matter of the present hickory handle specifications is incorporated in these proposed specifications, I believe they can be clearly presented for your consideration by pointing out their similarities and the essential differences and by reading only those parts of the full text that apply primarily or in large part to ash handles.

(He then read the section headings and commented on some of the provisions of the specifications.)

Mr. Cornell: I make a motion that these specifications be adopted for publication in the Manual, replacing the present hickory handle specifications.

(The motion was seconded, put to a vote and carried.)

Mr. Cornell: The committee also recommends the following changes in the material now in the Manual.

That Plan No. 7-46 be adopted for publication in the Manual superseding Plan No. 7-41.

Plan No. 7-46 retains the same jaw spread in both the open and closed positions, as the present plan, but has about 4½ in. wider spread in the handle grips when in the closed position; also the points have been changed from the present cross-sectionally square point to a peavy point with one flat face of the triangle up. The desirability of these changes was indicated by complaints that when pulling the tongs toward the body there was a tendency to spread the hands apart, allowing the tongs to slip. There are now a few samples of the revised design in use and the reports have all been favorable.

I make the motion that Plan No. 7-46 be adopted for publication in the Manual superseding Plan No. 7-41.

(The motion was seconded, put to a vote and carried.)

Mr. Cornell: Your committee feels that Rail Fork—Plan No. 10 is not a satisfactory tool and that its limited use and acceptance by the railroads does not warrant its continuation in the Manual.

I make the motion that this plan be removed from the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Cornell: Definition of Grades—ash handles and specifications for track shovels shown on page 5-53 of the Manual.

(He read the material under 25. Track Shovel—Plan 21.)

Mr. Cornell: It will be noted these specifications are the same as now in the Manual except Section 3. Handles and Tops. Reference is now made to the Ash and Hickory Handle Specifications which read as follows:

"Handles shall be made of Ash and shall conform to Grade AA as set forth in the general specifications for track tools. The tops of handles shall be of the design specified and shall conform to plans that are made a part of this specification."

I make the motion that the above recommended deletion be made and that the Track Shovel Specifications, as revised, be adopted and inserted on page 5-49 in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Cornell: Ballast Forks—Specifications shown on page 5-54 of the Manual. It is proposed that these specifications be revised to read as follows and inserted on page 5-49.

(Mr. Cornell then read the material under 26. Ballast Fork—Plan No. 22.)

I move that these revised specifications be adopted and inserted in the Manual on page 5-49.

(The motion was seconded, put to a vote and carried.)

Chairman Schram: Assignment 4—Plans for switches, frogs, crossings, spring and slip switches—will be presented by Mr. Caruthers, the chairman of Subcommittee 4.

E. W. Caruthers (Pennsylvania): The committee during the year, in view of the encouraging service results from the frogs of heavier construction, has been preparing plans covering the entire series. They are not as yet ready for presentation, but we hope in the course of the next year to have that material available.

(Mr. Caruthers read the material having to do with revisions in Portfolio of Trackwork Plans, including withdrawal of emergency provisions.)

Mr. Caruthers: I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Schram: Assignment 6—Design of and stresses in tie plates—is a combination of two previous assignments of the Track committee. The two branches of this subject, design and stresses, have been combined, and we now have one tie plate subcommittee. The report of that subcommittee will be presented by Mr. Macomb, the chairman.

J. de N. Macomb (Inland Steel Company): Through an oversight, the recommendations about to be presented were omitted in the printing of Bulletin 458. However, they deal entirely with the yellow sheets which have appeared in the front of Chapter 5 for the past several years, so that the members of the Association are entirely familiar with them. It is desired to dispose of the yellow sheets by transferring some of the material into the chapter itself as white sheets, and by eliminating other parts entirely. Thus, we propose to:

Delete Specifications for Medium-Carbon Steel Tie Plates—1942, shown on pages 5–1 to 5–3, inclusive.

Adopt as recommended practice for publication in the Manual, Specifications for Soft and Medium Steel Tie Plates now shown on pages E–5–3 to E–5–5, inclusive, of Emergency Specifications (yellow sheets) adopted December 31, 1942, Revised July 1, 1944.

The principal difference in these specifications is that the emergency document included the soft grade. I move the substitution.

(The motion was seconded, put to a vote and carried.)

Mr. Macomb: Withdraw the introductory material on emergency designs of tie plates (yellow sheets) appearing on page E–5–7.

That was simply explanatory of the emergency plans put out two or three years ago and, as the plans are being disposed of, the material is no longer necessary. I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Macomb: Adopt as recommended practice and for publication in the Manual, the following:

Plan C—AREA 13-in. Tie Plate for Use with 112-lb. RE Rail, now shown on page E–5–6 (yellow sheet).

Plan D—AREA 14-in. Tie Plate for Use with 131-lb. RE Rail, now shown on page E–5–9 (yellow sheet).

I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Macomb: Withdraw the emergency tie plate plans E and F, appearing on pages E–5–10 and E–5–11 (yellow sheets).

Those embodied very minor modifications, respectively, of Plans 2 and 3 still in the Manual.

I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Macomb: The remainder of the report will be found in Bulletin 458. This is a progress report, submitted as information, and covers stress measurements in seven designs of tie plantes for 131-lb. RE rail on the Southern Railway near Chattanooga, Tenn. This is part of the work of Mr. Magee's research staff and is presented as information.

I might add as information that during the past two years a special committee of the American Iron and Steel Institute has worked with the Emergency Committee on Roadway and Track Problems of the Association of American Railroads, looking to the simplification and standardization of tie plates.

Since the emergency committee went out of existence as of V-J day, this cooperative effort has been taken over by the Track committee under its Assignment 6, and this work has already been undertaken by this subcommittee.

The investigation so far has consisted of compiling records of tie plate sections which the manufacturers are equipped to produce and the sections required by the railroads. It remains to compose the differences between these records, much as was done in connection with rail sections during the war period. Considerable work has also been done on variations on tie plate punchings, but this has not progressed as far as that on the sections.

That is the extent of the report of Subcommittee 6.

Chairman Schram: The report on Assignment 7 covers the welding of manganese castings in special trackwork. Various tests have been made in connection therewith and will be presented by Mr. Bishop, the chairman of the subcommittee.

F. J. Bishop (Akron, Canton & Youngstown): The report on the assignment this year consists of a description of the observed service performance of the special test castings on the Milwaukee and the specially welded frogs on the Toledo Terminal at Toledo. The detailed program of the investigation and a description of the Milwaukee and Toledo Terminal test installations may be found in the rather voluminous report published last year (Proceedings, Vol. 46, page 525) and in previous reports of the subcommittee.

I call your attention to the conclusions. After four or five years' work we developed a series of conclusions last year, and this year's work has indicated that the results obtained in the Milwaukee and Toledo tests during the past year do not change the tentative conclusions given on page 567 of last year's report.

The Toledo Terminal test is to be continued. Additional frogs have been added to the original eleven in order to obtain more data pertaining to the welding technique, etc.

This is offered as information.

Chairman Schram: The next assignment—Effect of lubrication in preventing frozen rail joints—will be presented by the chairman of the subcommittee, Mr. C. W. Breed.

C. W. Breed (Chicago, Burlington & Quincy): This is a progress report submitted as information. Previous laboratory tests on joint lubrication made on a slippage machine designed by Mr. Magee, accumulated considerable data which will be included in a later report.

To verify the laboratory data and determine the effects of weather and traffic, it was necessary that a field test be made of those lubricants which appeared most promising in the laboratory tests.

Mr. Magee, who was in charge of the tests, requested a five-mile test section of track, with approximately level grade, no curves, heavy rail, and with fairly heavy traffic. He wished also to have the location sufficiently near Chicago to be accessible

for frequent observations by members of his staff. The committee selected a location on the Burlington, about 70 miles west of Chicago. The chart on page 525 shows the principal characteristics of the test track. Five miles of track were divided into 20 sections of rail, each one half a mile long. Each section consists of approximately 68 joints. Lubricants were applied, as shown on the chart, at the time of the rail relay.

Chairman Schram: Assignment 9—Recommendations on number and placing of anti-creepers for various conditions—will be presented by Mr. E. E. Martin, chairman of the subcommittee.

E. E. Martin (Pennsylvania): The work of this committee comprises the service testing of various methods of rail anchoring at two locations on the Chicago, Milwaukee, St. Paul & Pacific Railroad in gravel ballast track; one location being in the westward double-track main line near Mauston, Wis., laid with 131-lb. RE rail, and the other on the single main line track near Burlington, Wis., laid with 112-lb. RE rail. A third test is located on the Illinois Central System northward track of the three-track main line near Kankakee, Ill., laid with 112-lb. RE rail in rock ballast.

The field and office work is conducted by the engineering staff of the Association of American Railroads, assisted by the engineering staff on each of the respective railroads. The report includes information of interest based on accumulated data from two years of service testing, which included measurements of rail creepage, tie movement, joint gap openings and observations of the condition of alinement as noted in each test.

At this period of the test at three locations, the summaries of the results obtained have been reduced to conclusions. On page 533, is the conclusion based on the Milwaukee test near Mauston, Wis., gravel ballast, one-direction traffic.

(Mr. Martin then read the conclusions on page 533.)

Mr. Martin: On the Illinois Central test with rock ballast, one-way traffic, the conclusion is: Based upon the test measurements to date, anchorage methods B and C shown in Fig. 7, have shown the least satisfactory performance, and methods F, G, H and I the most satisfactory.

For the Milwaukee test, single-track between Burlington and Kansasville, Wis., the conclusions are expressed on page 545.

(Mr. Martin then read the conclusions.)

Mr. Martin: This report is offered as information.

Chairman Schram: We have no report on subjects 10 or 11. I may say that we expect to have our investigation far enough along on subject 10 so a report can be made next year.

That concludes the work of Committee 5.

Vice-President Akers: May I congratulate Mr. Schram and his committee for the valuable report just presented. You are now excused with the thanks and appreciation of the Association. (Applause)

Discussion on Economics of Railway Labor

(For Report, see pp. 169–178.)

Vice-President Akers: The chairman of this committee is Mr. H. A. Cassil. Owing to serious illness, Mr. Cassil cannot be here today, and the report will be presented by Mr. J. S. McBride who will succeed Mr. Cassil as chairman at the end of this meeting. Although Mr. Cassil is not present, we wish to make mention here of the very fine work he has done during his term as chairman of this committee.

Vice-Chairman J. S. McBride (Chicago & Eastern Illinois): We are saddened that, because of the illness of the chairman, he cannot be here today to present this report, but we wish him a speedy recovery.

The committee is reporting on two subjects this year, 5 and 7, but reports progress and study on several of the other subjects.

Subject 5—Economies that can be effected by reduction of clerical work through the elimination and simplification of reports—will be presented by Mr. C. C. Haire, chairman of the subcommittee.

C. C. Haire (Illinois Central): The report is a brief statement of conditions that the committee has been investigating for several years.

Everyone here knows, when the Association was founded at the beginning of this century, clerical work of the railroads was rather simple. Today there is a well founded feeling that we are becoming saturated with so-called paper work. While the government agencies are, in part, the cause of a large number of reports and statistics, yet the railroads themselves cannot escape responsibility for contributing to the situation.

We found in our investigation that railroads have a variety of routines and accounting systems so dissimilar that the committee could reach but one conclusion—that if some are right, then many must be wrong.

In the maintenance of way departments we have found some simple time and material reporting methods that are not unduly burdensome. Some seem to have rather involved routine. Accounting viewpoints and methods are largely the basis for requiring maintenance forces to do more or less bookkeeping, but the accounting requirements should not be considered as wholly causing the increase in clerical work.

The committee has discussed this subject on two pages and has arrived at a number of conclusions on page 171. I will not read them. They speak for themselves, and we commend them to you.

I say, in addition to the suggestions offered in these conclusions, some relief to the overall situation may be afforded by mechanizing some of our routines, by using business machines and by standardization. The situation, however, demands a strong, aggressive counter activity to reduce the present burdens.

This report is offered as information.

Vice-President Akers: It is so received.

(President Miller presiding)

Vice-Chairman McBride: The next is subject 7—Methods of housing and transporting maintenance of way forces to reduce the use of motor cars and camp cars.

Replies were received from 49 roads in all sections of the United States and Canada, which should be representative of present practices. One part of the report deals with the housing and the other part with the transportation feature. A far majority of the roads reporting have used no method of housing other than camp cars.

The housing used varied from 10-ft. by 12-ft. tents, and portable houses of various sizes, to more elaborate fixed houses of permanent construction. This is set out in more detail in the report, with the costs of the various methods of housing used.

Two roads reported using, to a limited extent, automobile trailers for housing small gangs. It is interesting to note that no road reported that it was not using camp cars, and three-fourths of the roads using other methods of housing definitely reported that they were also using camp cars.

The labor shortage during the war brought about the use of portable structures and, in many cases, even the use of permanent and semi-permanent buildings. In other cases the permanent buildings are a part of the regular facilities for housing section and terminal gangs in order to retain the required force at critical points.

In general, the matter of economy was not even considered in providing this housing. The use of trucks and buses for transportation was more general. Eighty-five percent of the roads are making use of trucks or buses, or both, as well as motor cars. These highway vehicles are transporting every class of maintenance of way forces. The force so transported varied from a single water service man to a 150-man extra gang.

These vehicles, in addition to transporting men and equipment in many cases are also used for transporting material. The use of highway vehicles greatly increased during the war, because of the necessity of transporting men to points where there was a shortage of labor or to get forces off dense traffic tracks. This increase was such that many roads found it necessary to rent both trucks and buses.

Some of the roads made use of trucks prior to the war and advise they expect to expand their use. A majority of the roads using trucks own them. More than two-thirds of the roads using trucks for transporting their men advise there is economy in such use of highway vehicles. Many say that, while there are definite savings, the exact figures are not available. Others report that from one to three hours per day per gang are saved, and still others that the traveling time is reduced 50 percent on the highway.

One road with 80 owned trucks estimated its savings at 25 to 100 percent, after allowance for cost of operation, repairs, interest and depreciation.

While there are economies in the use of highway vehicles, to obtain these economies, their use must conform with a well-thought plan of organization and operation.

The conclusions of the committee are found on pages 177 and 178. The report is submitted as information.

President Miller: And will be so received.

Vice-Chairman McBride: It is my sad duty to refer to the death of Mr. H. E. Smith, a member of this committee, district engineer of the Canadian National Railways. Mr. Vandenburgh will present a memoir for the record.

E. C. Vandenburgh (Chicago & North Western): This memoir was adopted by the members of Committee 22:

Henry Emmet Smith

Henry Emmet Smith, district engineer, Canadian National Railways, and a member of this committee, died suddenly at Montreal, Que., on January 15, 1946. He was born May 4, 1894, at Ottawa, Ont., and received his higher education at McGill University, graduating in civil engineering in 1917.

Mr. Smith entered the service of the Grand Trunk Railway (now part of the Canadian National Railways) on May 1, 1917. The following year he entered military service and served overseas with the Canadian Siege Artillery, returning to the Grand Trunk on June 1, 1919. His entire professional career was with that railroad and the Canadian National Railways.

He became a member of the American Railway Engineering Association in 1941 and was appointed to membership of Committee 22—Economics of Railway Labor in 1942. He continued as a member of this committee until his death and rendered valuable service throughout his years of membership.

The committee records here its personal regard and its appreciation of his professional accomplishments. His death is sincerely regretted and his loss will be deeply felt by both the committee and the Association.

The Committee on Economics of Railway Labor

Vice-Chairman McBride: That concludes the report of Committee 22.

President Miller: Before excusing this committee, I want to make a comment or two of my own in connection with the subject, economics of railway labor. In our industry or any other industry we deal with just two things. In the last analysis, material, unless reformed or reshaped for useful purposes, remains where the Creator put it. It is touched by labor and it comes under direction. Therefore, in dealing with the economics of railway labor, we are really dealing with the economics of all labor.

We owe it to ourselves and the institutions we work for to give thought to our work, no matter what committee is handling what work. But this particular committee is dealing with something fundamental—with respect to just what labor means, what it is expected to do, how it will come under direction. Who, after all, is not a laborer in some field, whether he is directing or whether he is being directed. I think it is an expanding thing. The best thought we can give to it is none too good.

This particular subject is very close to my heart, and I think it is well worthwhile that we all give it serious study, because it is the foundation of a structure that we are building for ourselves. There are a lot of structures being built upon the meaning and what is implied in this subject matter.

We are very much indebted to you, Mr. McBride, for your able presentation of an excellent report of this committee, which is now excused with the thanks of the Association. (Applause)

Discussion on Wood Bridges and Trestles

(For Report, see pp. 215–224.)

(President Miller presiding)

Chairman S. F. Grear (Illinois Central): We have no revisions of the Manual to offer, but we have three progress reports.

Assignment 6—Specifications and design of fastenings for timber trestles, including metal joint connectors—will be presented by the chairman of the subcommittee, Mr. W. O. Nelson.

W. O. Nelson (Baltimore & Ohio): The report of this subcommittee, Assignment 6, consists of a set of tentative specifications to replace those contained in the Manual on pages 7–5 and 7–6 under the heading Specifications for Metal Details Used in Wood Bridges and Trestles, and adopted by this Association in 1936.

I shall not read this new set of specifications which we now propose, but I will comment briefly on the reason why we are revising the old specifications. The need for this revision has arisen from several causes. One of them is the development of new and distinctive types of fastening and connectors that have been developed since the adoption of those specified, and which are in general use at the present time.

There is another reason—the meagerness of the specifications themselves. There is still another reason—several references to specifications formulated by Committee 15—Iron and Steel Structures which have recently been revised.

The specifications now presented list materials entering into the manufacture of metal fastenings and connectors and include wrought iron, malleable iron, cast iron, rolled steel and cast steel, to each of which has been assigned a current ASTM specification applicable thereto.

This is followed by a listing of the various types of fastenings, such as nails, spikes, drift pins, through bolts, washers, packing spools and separators, lag screws,

special castings, cap-stringer fastenings, metal joint connectors, brace plates and washer plates.

Statements follow each of these types, stipulating the material of which they shall be made and certain limitations on the dimensions, design or workmanship.

This report is presented with a request for comments and criticism, pending action on the part of the Association next year.

Chairman Grear: Assignment 7—Procedure to be followed in renewing creosoted timber ballasted deck trestles. Some of us have been building this type of trestle for a good many years, and it is getting to the point where quite a few of them need renewal.

The subcommittee has prepared quite a report. This is new and will have to go over another year at least. We will greatly appreciate any comments on this report. The report will be presented by Mr. H. T. Livingston.

H. T. Livingston (Chicago, Rock Island & Pacific): I hesitate somewhat reading this report but I don't believe any extemporaneous remarks would improve the wording, which has already been gone over by the subcommittee. There will probably be some difference of opinion as to procedure, due to some difference in the types of design of various railroads. Some railroads have stringers chorded the same as in open deck trestles, and others have lap joints over the caps.

(Mr. Livingston then read the introduction.)

Mr. Livingston: Of course, that "every fifth bent" is empirical because it is obvious that in some territories one pile will possibly suffice to indicate the length of piling required throughout the entire structure.

(He then read page 219, down to the first full paragraph on page 221.)

Mr. Livingston: There will probably be some difference of opinion as to the advantage of driving a line of corresponding piles throughout the length of the bridge, but it was the consensus of the committee that we would probably secure better penetration by that method than where you drive each entire bent in turn, and especially if you drove the outside pile first because of the "tightening up" around the pile as you drove it.

(He then read beginning with the first paragraph on page 221 down to "During the entire time," etc., near the bottom of that page.)

Mr. Livingston: It might seem rather senseless to put in a sentence of that type but I know of several jobs that burned just after they had been completed. I recall particularly, a bridge on a railroad in the south, where they just finished cleaning up the debris. When the men went in to dinner, the structure caught fire from one of the refuse piles, and the fire was beyond control when they returned, so they had to start all over again.

(He then concluded the reading.)

Mr. Livingston: This is submitted for further consideration.

President Miller: The report will be received as information.

Chairman Grear: Assignment 8—Design of creosoted timber pile piers for long spans—will be presented by Mr. W. D. Keeney, chairman of the subcommittee.

W. D. Keeney (American Wood-Preservers' Association): In this part of the report, two plans for timber pile piers for spans of 150 ft. are offered for your consideration. An alternate arrangement of capping is shown for each plan, permitting the lower tier to be placed either normal to or in the direction of traffic.

Caps built up of two 8 by 16-in. timbers on edge are also shown as alternates to the conventional 14 by 14-in. sizes in common use.

This part of the report is submitted as information, with the hope that plans may be perfected next year for inclusion in the Manual.

President Miller: The report will be received as information.

Chairman Grear: Before the committee is dismissed, Mr. H. M. Church wants to make a suggestion in regard to grouping of piling.

H. M. Church (Chesapeake & Ohio): During the time I was chairman of this committee the subject of pile driving, with weight of hammer, and so forth, was given considerable study for a number of years.

I believe that enough new information has come to light in recent years, involving bearing values and the behavior of piles in groups to warrant a reopening of the subject. Instead of assigning it to this committee the subject should be handled as a collaborative project, particularly in view of the very extensive investigations of steel, wood and concrete piling in a number of our harbors.

I offer this as a suggestion to be given consideration by the Committee on Outline of Work, since a similar suggestion was made by the Building committee.

President Miller: The matter will be so handled through the Committee on Outline of Work, if you will get in contact with that committee with your suggestion.

Chairman Grear: That completes the report of Committee 7.

President Miller: Mr. Grear, your committee has given us an interesting and informative report. You are doing an important work, and the Association thanks you for what you have done and excuses your committee with thanks and appreciation. (Applause)

Discussion on Masonry

(For Report, see pp. 205–214.)

(President Miller presiding)

Chairman A. N. Laird (Grand Trunk Western): The formal report of the committee consists of revision of the Manual. At the request of Mr. Boyd, who is chairman of that subcommittee, I will present that report.

The first item of revision of Manual consists of a number of deletions of terms and definitions appearing in the glossary of the Manual. This action by the committee has been made after consultation with the office of the secretary of the Association, in an effort to simplify and minimize the amount of subject matter appearing in that part of the Manual. The committee recommends the deletion of the terms listed under item 1, and I wish to move that the terms included under item 1 be deleted and removed from the glossary of the Manual, including their definitions.

(The motion was seconded, put to a vote and carried.)

Chairman Laird: Under item 2 are included revisions of definitions of terms where it is felt by the committee that the present definition doesn't truly represent the meaning used in the context of the specifications.

(Chairman Laird then read the revisions of definitions of terms in the glossary of the Manual.)

Chairman Laird: I move the adoption of the proposed changes.

(The motion was seconded, put to a vote and carried.)

Chairman Laird: The third section is to incorporate new terms and definitions in the glossary.

(He then read the material under item 3.)

(Chairman Laird: I move the adoption and inclusion of these terms and definitions.

(The motion was seconded, put to a vote and carried.)

Chairman Laird: Item 4 is an editorial change in the heading of specifications under the subheading "Design Section" to make it conform to the other portions of Chapter 8 of the Manual. I move the adoption of this change.

(The motion was seconded, put to a vote and carried.)

Chairman Laird: Item 5. The committee formerly had a clause in its specifications referring to a "standard AREA live load" for railroad bridges. This is an ambiguous term because no such standard is in existence. There are certain recommended values but they do not have the status of "standards." To clarify that point, the committee recommends a revision to read as follows:

(Chairman Laird then read the material under item 5.)

Chairman Laird: This provision will bring the loadings and loading requirements of the two sections of the Manual into harmony.

I move the adoption of this change.

(The motion was seconded, put to a vote and carried.)

(Chairman Laird then read the material under item 6.)

Chairman Laird: This change is to bring the method of tests more definitely into line with the practice. I move the adoption of this change.

(The motion was seconded, put to a vote and carried.)

Chairman Laird: In item 7 it is proposed to revise the details of Figs. 15 to 18, inclusive, Retaining Walls, appearing on page 8–86 of the Manual. These changes are shown on the following page. The figures are not fundamentally changed; only those items which were not clear in the former diagrams have been modified. These changes relate to surcharge loadings on retaining walls.

I move the adoption of these revised diagrams to replace those now appearing in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Laird: Item 8. Revise paragraph 11, Section 315, Design of Concrete Transmission Poles, appearing on page 8–75. This change, again, is necessary to clarify the reference to the specification for reinforcing steel. The proposed form is as follows:

(He then read the proposed form.)

Chairman Laird: I move the adoption of this change.

(The motion was seconded, put to a vote and carried.)

(Chairman Laird read the material under item 9, and moved the adoption of the change. The motion was seconded, put to a vote and carried.)

Chairman Laird: I would like to combine the recommendation of item 10 and item 11. During the war the committee and the Association had approved the use of War Emergency Specifications for Portland Cement, ASTM Designation EA-C 150. It is now proposed that these be formally withdrawn and that they be replaced with Specifications for Portland Cement, ASTM Designation C 150–44.

This specification has been printed in Bulletin 457 (page 211). At the end of these specifications, reference is made to other ASTM standard specifications, dealing with methods of tests for portland cement and sampling. These are an integral part of the specification as submitted.

The committee also recommends the inclusion and the revision of ASTM specification references appearing under item 11, in order to clarify the exact year of adop-

tion by the ASTM. It is the new policy of Committee 8, throughout the body of the report, to make reference to ASTM specifications simply by the basic designation such as C 150 or C 114, without giving the year of adoption.

The reason for this is that the committee wishes to reserve for the benefit of the Association the right to review and make changes and adopt changes only after it has reviewed them. It also simplifies revision of the Manual. The change is made at the request of the secretary.

I move the adoption of the revisions of the ASTM specifications now appearing on page 8–25 of the Manual and incorporated under item 11, and also the adoption of ASTM Specification C 150–44, Standard Specification for Portland Cement, replacing the former specifications which appear in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Laird: This concludes the formal report of Committee 8.

If I may have your permission for a brief moment, I would like to report that, under the several assignments which Committee 8 has before it, substantial progress has been made by a number of the subcommittees. These subjects are of a nature which do not permit a report ordinarily on the first year of assignment, and some of them are continuing, but very definite progress has been made on a revision of the design section of the Manual to bring it to a point currently where it incorporates recent advances in engineering practice.

There is also in course of preparation a manual of recommended practice for concrete work and construction, which should prove very beneficial to the membership of this Association and to the railroad engineering profession.

This concludes my report.

President Miller: Mr. Laird, your three-year term as chairman of Committee 8—Masonry, terminates at this time and I wish to thank you for your valuable service to the Association. A most excellent report was made by your committee, through you. The committee is now excused with our sincere thanks. (Applause)

Discussion on Iron and Steel Structures

(For Report, see pp. 243–245.)

(President Miller presiding)

Chairman J. E. Bernhardt (Chicago & Eastern Illinois): Committee 15 reports this year on but one assignment—Revision of Manual. Mr. O. E. Selby is absent on account of illness*, and I will present the report of the subcommittee.

The committee recommends the following changes in the Specifications for Steel Railway Bridges:

(Chairman Bernhardt then read the material under Distribution of Live Load, and his motion for adoption was seconded, put to a vote and carried.)

(Chairman Bernhardt read the material under Unit Stresses, and his motion for adoption was seconded, put to a vote and carried.)

(Chairman Bernhardt read the material under Fit of Stiffeners, and his motion for adoption was seconded, put to a vote and carried.)

(Chairman Bernhardt read the material under Specifications for Erection of Steel Bridges, and his motion to adopt was seconded, put to a vote and carried.)

Chairman Bernhardt: The AAR has during the past five years contributed a total of $25,000 to assist in defraying the expense of conducting fatigue tests of welded

* Mr. Selby died on March 15, 1946.

joints. Including the contribution of certain services by the University of Illinois, there has been spent to date on these tests a total of more than $60,000. The work has now been nearly completed.

The work, from its inception, has been under the direction of a member of Committee 15, Professor Wilbur M. Wilson. I am sure you will be interested in hearing Professor Wilson address you on the subject "Fatigue Strength of Structural Welds." Professor Wilson! (Applause)

Fatigue Strength of Weldments Used to Reinforce and Repair Steel Bridge Members

By Wilbur M. Wilson

Research Professor of Structural Engineering, University of Illinois, Urbana, Ill.

Introduction

Although fatigue has been recognized as a factor in structural design for many years,[1] it was only when a few fatigue tests of structural members became available that it was realized that fatigue tests of small machined specimens, although of great value for the purpose for which they were intended, were not a reliable indication of the fatigue strength of fabricated steel structural members. Considerable, although wholly inadequate, experimental data on the fatigue strength of fabricated steel structural members have accumulated during the last decade. Some of the published reports cover fatigue tests of riveted and bolted structural members,[2] others cover fatigue tests of welded structural members.[3] The latter investigations were made as the work of the Committee on Fatigue Testing (Structural) of the Welding Research Council of the Engineering Foundation. A paper by the present author entitled, Fatigue, A Factor in Structural Design,[4] is, as its title indicates, a general discussion of the factors that are the most likely to cause the fatigue failure of a structural member. Quoting from this article, ". . . , the factors that have the greatest effect upon the fatigue strength of structural members are:

"1. Ratio of the minimum to the maximum stress in the cycle.
"2. Number of cycles to which the member is subjected during its life.
"3. Magnitude of the stress-raising factor."

Another paragraph from the same article presents the same facts in the following form.

"The condition most likely to result in a fatigue failure is a combination of: (1) a bad stress raiser, (2) a small (algebraically) ratio of minimum to maximum stress in the stress cycle, and (3) a large number of cycles of near maximum stress during the life of the structure."

[1] AREA Specifications for Steel Railway Bridges, paragraph 215.
[2] University of Illinois Engineering Experiment Station Bulletins 302 and 317.
[3] University of Illinois Engineering Experiment Station Bulletins 310, 327, 344 and 350.
[4] Journal of the Western Society of Engineers, Vol. 49, No. 2, June 1944, page 51.

The above are basic factors that should be kept in mind in considering the possibilities of fatigue failures of structural members.

The fatigue tests of welded structural members conducted by the author at the University of Illinois and reported in various bulletins of the Engineering Experiment Station, were made under the general supervision of the Committee on Fatigue Testing (Structural) of the Welding Research Council of the Engineering Foundation of which Jonathan Jones was chairman. The cost of the investigation, which was begun in 1938 and is still under way, has already exceeded $100,000. Of this amount, the Association of American Railroads, upon the recommendation of Committee 15 of the American Railway Engineering Association, has contributed $5000 per year for the last five years.[5] In addition to the investigation of fundamentals, which were of interest to all contributors, two series of tests were made specifically because of their interest to the railroads.[6] One series consisted of fatigue tests of flexural members and the other consisted of fatigue tests of bridge reinforcements. The present paper is a presentation of the work of these two subcommittees.

In considering the work presented in this paper, the fact should be borne in mind that the experimental relations resulting from fatigue tests are largely empirical. Moreover, the expression, fatigue strength, is without definite meaning unless properly defined, since the fatigue strength depends upon the ratio of the minimum to the maximum stress in the stress cycle, and it also depends upon the number of cycles that the member is to withstand before failure. To illustrate, it is meaningless to say that the fatigue strength of a certain I-beam is 24,000 lb. per sq. in. To be definite, it is necessary to say that the fatigue strength of a member, corresponding to failure at 100,000 (or some other number of) cycles in which the stress varies from zero to a maximum tension (or any other ratio of minimum to maximum stress) is 24,000 lb. per sq. in.

The writer, in most reports, has given two values of the fatigue strength, one corresponding to failure at 100,000 cycles, expressed as $F_{100,000}$, and the other corresponding to failure at 2,000,000 cycles, expressed as $F_{2,000,000}$. The former has been considered as the value of interest in designing members subjected to one stress cycle for each passage of a train, such as the chords of a truss; the latter has been considered as the value of interest in designing members subjected to a cycle of stress for each passage of an axle or small group of axles, such as stringers, floor beams and hip verticals. These values have been selected more or less arbitrarily but would seem to be as acceptable as any with our present knowledge of the subject.

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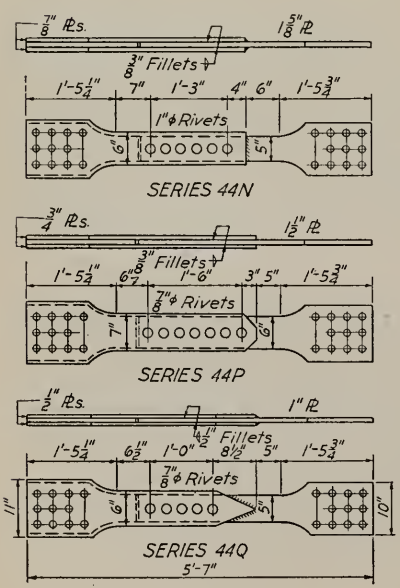
[5] Other contributors were: The Chicago Bridge and Iron Company; the Public Roads Administration, Federal Works Agency; the Bureau of Ships, Navy Department. Materials and services were contributed by: The Carnegie-Illinois Steel Corporation; the Bethlehem Steel Company; Lukenweld, Inc.; the Bureau of Ships, Navy Department; the G. E. X-Ray Corporation; the Chicago Bridge and Iron Company; the Lincoln Electric Company; the Lasker Boiler and Engineering Corporation; the Aetna Iron and Steel Company; and the Union Carbide and Carbon Research Laboratories, Inc. The fatigue tests were made in the Arthur Newell Talbot Laboratory, and the metallurgical studies were made in the Metallurgical Laboratory, both of the University of Illinois. The contributions by the University of Illinois include space in the laboratories, together with utility services for the same, the time of regular staff members in supervising the tests and writing the reports, and the publication of numerous bulletins in which the results have been reported.

[6] These tests were planned by two subcommittees of the Committee on Iron and Steel Structures of the American Railway Engineering Association. One is known as the Subcommittee on Fatigue Tests of Flexural Members, of which G. M. Magee is chairman; and the other is known as the Subcommittee on Bridge Reinforcement, of which J. E. Bernhardt is chairman.

Work of the Subcommittee on Bridge Reinforcement

The increase in the loads above what the bridges were designed to carry and the continuation of bridges in service beyond the time when they should have been replaced, have made it necessary to reinforce some members. The specimens which were used in the fatigue tests about to be described represent methods of reinforcement which have been used or which have been proposed for strengthening existing bridges.

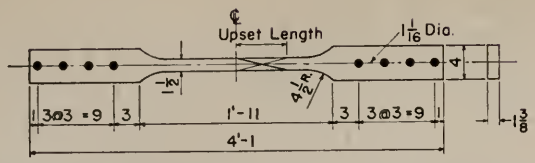
Eyebars of trusses become loose in service and should be tightened by shortening. One method of shortening them is to cut the eyebar, removing a short piece, and then splicing the two parts. Specimens 44N, 44P and 44Q of Fig. 1 represent splices that have been used by one railroad in shortening eyebars. They were subjected to fatigue tests in which the stress in the stress cycle varied from zero to a maximum tension. Values for $F_{100,000}$ and $F_{2,000,000}$ are given in the first and second columns of the table of Fig. 1. Values are given separately for the splice plates and the main plates, the values given being based upon the gross section in all instances. Each value is the average from three tests. The * adjacent to a numeral indicates the part that



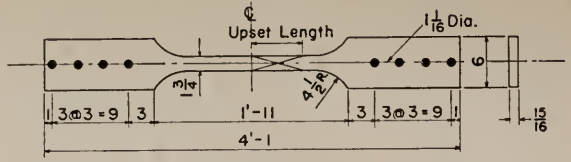
	Fatigue Strength Lb. per sq. in. (000 omitted)		*Static Ultimate Stress Lb. per sq. in. (000 omitted)*	
	At 100,000 cycles	*At 2,000,000 cycles*	*Net Section*	*Gross Section*
Main Plate	22.6	13.0	69.0	53.4
Side Plates	16.8*	11.1*	55.1	44.2*
Main Plate	23.8*	11.2*	70.8*	58.9
Side Plates	20.5	9.4	52.1	49.7
Main Plate	27.5	10.6	87.0	69.5
Side Plates	21.3*	9.5*	70.0*	58.2

* Part that failed.

Fig. 1.—Eyebar Splices.



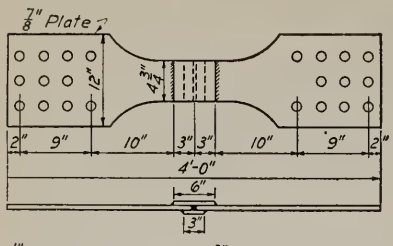
DETAIL OF WROUGHT IRON EYE BAR SPECIMEN



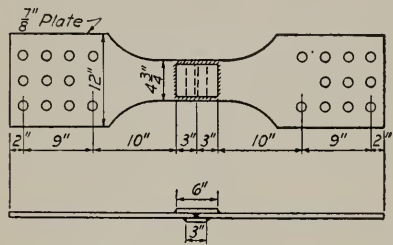
DETAIL OF STEEL EYE BAR SPECIMEN

TEST SERIES	DESCRIPTION OF TEST SPECIMEN	STRESS CYCLE KIPS PER SQUARE INCH	NUMBER OF CYCLES FOR FAILURE	AVERAGE FATIGUE STRENGTH KIPS PER SQUARE INCH		STATIC STRENGTH KIPS PER SQUARE INCH		LOCATION OF FATIGUE FRACTURE
				AT 500,000 CYCLES	AT 1,000,000 CYCLES	YIELD POINT	ULTIMATE	A B C D E
44Y	Wrought Iron	+ 0.8 to +31.6	837,600	32.7	28.4			B
	Eye Bars Not	+ 1.0 to +31.0	760,800					A
	Flame Shortened	+ 1.0 to +31.0	504,300					B
44X	Wrought Iron	+ 1.0 to +31.0	781,200	30.5	26.4			E
	Eye Bars	+ 1.0 to +31.0	280,300					C
	Flame Shortened	+ 1.0 to +31.0	1,284,500					E
44B	Steel	0 to +32.0	1,333,000	36.4	31.5	30.6	56.5	B
	Eye Bars Not	0 to +34.0	687,300					B
	Flame Shortened	0 to +32.0	1,017,000					B
44A	Steel	0 to +33.5	814,200	37.2	32.4	31.0	57.3	D
	Eye Bars	0 to +33.0	941,900					D
	Flame Shortened	0 to +33.0	956,500					D

Fig. 2.—Results of Fatigue Tests of Eyebars Shortened by Heat Treatment.



1/8" Strap plates for 44 Sa & 3/8" strap plates for 44 Sb
Transverse fillet welds:
1/8" for 44 Sa and 5/16" for 44 Sb



1/8" Strap plates for 44 Sc & 3/8" strap plates for 44 Sd
Fillet welds on all four edges of strap plates:
1/8" for 44 Sc and 5/16" for 44 Sd
No strap plates for Se

	Fatigue Strength Lb. per sq. in. (000 omitted)		Static Ultimate Stress Lb. per sq. in. (000 omitted)
	At 100,000 cycles	At 2,000,000 cycles	Net Section
44Sa	32.0	12.8	60.6
44Sb	30.1	11.1	60.8
44Sc	31.6	13.3	60.4
44Sd	30.9	11.8	60.2
44Se	34.5	22.7	60.3

Fig. 3.—Butt-Weld Joints With Butt Straps Attached With Fillet Welds.

failed. Failure was in the side plates for 44N and 44Q and, for these specimens, it may be presumed that the strength of the splice could have been increased to some extent by using a splice plate of somewhat greater section. However, failure of the main plate of 44P makes it seem unlikely that larger splice plates would have added greatly to the strength of 44N and 44Q.

The values of $F_{100,000}$ and $F_{2,000,000}$ for these spliced eyebars take on added significance when compared with a value for $F_{2,000,000}$ of 30,000 lb. per sq. in. for 7/8-in. plates in the as-rolled condition, that is, without welds or holes. The latter may be presumed to represent the fatigue strength of unspliced eyebars, a statement that is supported by the data in the table of Fig. 2.

Eyebars Shortened by Heating

Specimens representative of eyebars shortened by heating and upsetting, were used in the tests reported in the table of Fig. 2. The specimens were made from pieces cut from eyebars removed from old bridges. The specimens were first shortened by heating and upsetting and then the central portion of the specimens was reduced in width to insure against failure in the head. The reduction in width was accomplished by flame-cutting and milling 1/4 in. The upset portion of all shortened specimens was in the portion with a reduced width, as shown in the sketches at the top of the figure. The specimens at the left were made of wrought iron and those at the right were made of steel.

Nearly all specimens failed in or near the range between 500,000 and 1,000,000 cycles. For that reason, the comparison between the bars that were shortened and those that were not, was made on the basis of the values of $F_{500,000}$ and $F_{1,000,000}$. As for the tests reported in Fig. 1, each value of F is the average from three tests.

An examination of the values of F in Fig 2 reveals the fact that, for the wrought-iron bars, the bars that were upset had a slightly lower fatigue strength than the bars that were not upset. For the steel bars, the reverse was true. In neither case was the difference great enough to be particularly significant. No tests were made for failure at 100,000 cycles because the necessary stress would have exceeded the yield point of the material.

The tests reported in Figs. 1 and 2 indicate that shortening an eyebar by cutting and splicing greatly reduces its fatigue strength whereas shortening a similar eyebar by heating and upsetting does not affect its fatigue strength by a significant amount.

Butt Welds Reinforced With Butt Straps

Some engineers are reluctant to trust a butt weld connecting two plates and resort to the expedient of "reinforcing" the joint by grinding off the weld reinforcement flush with the base plate and attaching butt straps across the joint with fillet welds. Tests were made to determine whether or not the butt straps did actually increase the fatigue strength of the joint.

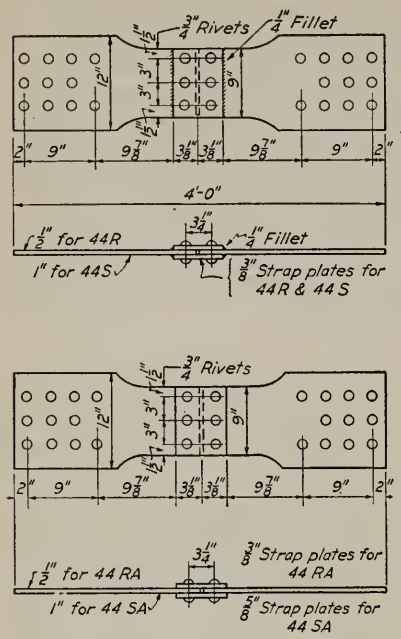
Four reinforced joints are shown in Fig. 3. Specimens 44Sa and 44Sb, shown in the upper sketch, have strap plates as wide as the main plate, and their only connection to the main plate is by means of transverse fillet welds. They differ from each other in that the butt straps are $\frac{1}{8}$ in. for 44Sa and $\frac{3}{8}$ in. for 44Sb. For specimens 44Sc and 44Sd, the butt straps are narrower than the main plate and are attached to the main plate with fillet welds on all four edges. They differ from each other in that the butt straps are $\frac{1}{8}$ in. for 44Sc and $\frac{3}{8}$ in. for 44 Sd.

Specimen 44Se has a transverse butt-weld joint in the as-welded condition. That is, it has no butt strap and the reinforcement is not ground off.

The results of the fatigue tests are given in the second and third columns of the table of Fig. 3. Each value of $F_{100,000}$ and $F_{2,000,000}$ is the average from three tests. It is of interest to note that for both types of specimens with butt straps, the ones with the thinner butt straps have the greater values of both $F_{100,000}$ and $F_{2,000,000}$, but the difference is not significant. The specimens with full-width butt straps have very nearly the same fatigue strength as the specimens with butt straps attached to the main plate on all four edges. It is of interest to note that the difference between $F_{100,000}$ and $F_{2,000,000}$ was much greater for all specimens with strap plates than it was for specimens without strap plates. The average value of $F_{100,000}$ was 17 percent greater for the 3 specimens without butt straps than it was for the 12 specimens with butt straps. In contrast with this, the average value of $F_{2,000,000}$ was 85 percent greater for the three specimens without butt straps than for the 12 specimens with butt straps. In other words, the so-called "reinforcement" actually decreased the fatigue strength of the butt-weld joints connecting the plates.

Double-Strap Riveted Butt Joint Reinforced With Fillet Welds Along the Edges of the Butt Straps

Some old riveted plate girders have web splices that were not designed to take moment. Tests were made to determine whether or not the flexural resistance of these girders could be increased by connecting the splice plates to the web by means of fillet welds.



	Fatigue Strength Lb. per sq. in. (000 omitted)		Static Ultimate Stress Lb. per sq. in. (000 omitted)	
	At 100,000 cycles	At 2,000,000 cycles	Net Section	Gross Section
44R	24.5	18.4	60.0	35.7
44S	20.3	10.4	62.7	37.4
44RA	19.4	17.0	47.0†	33.3
44SA	10.4*	7.8*	23.1*	16.4*

* Failed by Rivet Shear.
† Failed by Tearing out of Bolts to the Edge of Sheet.

Fig. 4.—Girder Web Splices Reinforced With Fillet Welds.

The details of the specimens are shown in Fig. 4. There are four kinds of specimens, two reinforced and two not reinforced. Of the two kinds of reinforced specimens, one has ½-in. main plates and ⅜ in. butt straps and the other has 1 in. main plates and ⅝-in. butt straps. Likewise, of the two kinds of nonreinforced specimens, one has ½-in. main plates and ⅜ in. butt straps and the other has 1 in. main plates and ⅝-in. butt straps. The corresponding reinforced and nonreinforced specimens are identical except for the reinforcement.

The fatigue specimens were tested on a cycle in which the stress parallel to the long axis varied from zero to a maximum tension. At first glance this would not seem to be equivalent to the loading due to flexure of a moment splice in a girder web. It should be noted, however, that the action on these narrow specimens loaded in this manner, is similar to the action on a longitudinal strip adjacent to the flange of a girder web except for the small shear carried at the center of span.

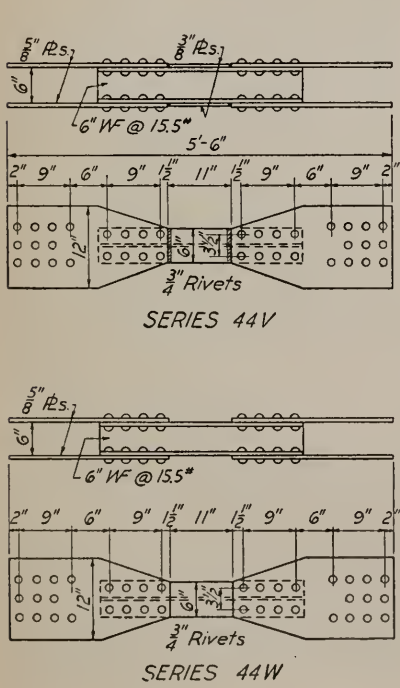
The results of the tests are given in the table of Fig. 4. The values of $F_{100,000}$ and $F_{2,000,000}$ are for the stress in the main plate and are based upon its gross section. Each value is the average from three tests. Specimen 44SA, the unreinforced specimens with a 1-in. main plate, failed in the rivets. All others failed in the main plate, 44RA failing on a section through the rivet holes and 44R and 44S failing at the edge of the welds.

The welds of 44R, the reinforced specimen with a ½ in. main plate, protected the rivets and protected the section of the main plate through the rivet holes. However, the main plate was so thin that the pair of opposite fillet welds, one on each side of the plate, acted as geometrical stress raisers and greatly weakened the plate so that the reinforcement did not add greatly to the fatigue strength of the joint, the increase in its fatigue strength being 26 percent and 8 percent for $F_{100,000}$ and $F_{2,000,000}$, respectively.

The welds of 44S protected the rivets and, because of its thickness, 1 in., the plate retained a fair value for its *total* fatigue strength but it had a relatively small *unit* fatigue strength. The values of $F_{100,000}$ and $F_{2,000,000}$ were 20,300 and 10,400 lb. per. sq. in., respectively. The corresponding values of the total fatigue strength for the specimen as a whole, were 95 percent and 33 percent greater, respectively, than the corresponding total values for the specimens with 1 in. plates not reinforced which broke in the rivets.

Reinforced Diagonal Truss Members

The diagonal members of riveted trusses usually fit between and are riveted to gusset plates at the ends. Members of this type can be reinforced by attaching plates to the member and welding them to the gusset plates at the ends. If the reinforcing plate has the same thickness as the gusset plate there will be no abrupt change in section at the ends of the reinforcement. By using this expedient, the geometrical stress raiser which usually occurs at the end of reinforcing plates, is eliminated. Specimen 44W of Fig. 5 represents a truss member that has not been reinforced and



	Fatigue Strength Lb. per sq. in. (000 omitted)*		Static Ultimate Stress Lb. per sq. in. (000 omitted)
	At 100,000 cycles	At 2,000,000 cycles	Net Section
44V	27.0	13.4	47.5 (Ult. load 482,000 lb.)
44W	27.8	13.8	59.3 (Ult. load 214,400 lb.)

* Based on Gross Section.

Fig. 5.—Reinforced Truss Members.

specimen 44V represents the same type of member after it has been reinforced. In this instance the end plates, which correspond to the gusset plates, had to be made thicker than the reinforcing plates to insure against failure through the holes in the head. Both types of specimens were tested on a cycle in which the stress varied from zero to a maximum tension. The results of the fatigue tests are given in the second and third columns of the table of Fig. 5. Each value is the average from the tests of three specimens, and the unit stress is based upon the gross area of the specimen. It is of interest to note that the unit fatigue strength was only slightly less for the reinforced specimen than it was for the specimen that had not been reinforced, indicating that, insofar as fatigue strength was concerned, the material that was added developed practically its full value. The unit static strength was less for the reinforced specimen than for the specimen that was not reinforced. However, the increase in section was so great that the total static strength was more than twice as great for the reinforced specimen as it was for the specimen that was not reinforced.

As stated above, the effectiveness of this type of reinforcement is due to the fact that conditions were such that there was no severe geometrical stress raiser at the end of the reinforcement.

Flexural Fatigue Tests

The stringers of bridges and short beam spans are subjected to a large number of stress cycles and the cycle is one for which the minimum stress is nearly zero. That is, they are subjected to two of the conditions that increase the possibilities of failure by fatigue. If, in addition, there are abrupt changes in the flange section, conditions that result in severe geometrical stress raisers, the stringers of bridges are subjected to all three of the conditions that are conducive to fatigue failure, these conditions being: (1) A small ratio of minimum to maximum stress in the stress cycle, (2) a large number of cycles during the life of the structure, and (3) a large stress raising factor. Because of these facts, flexural fatigue tests of stringers seemed to be desirable.

The flexural fatigue tests of stringers were made in one of the regular 200,000 lb. fatigue machines adapted to these tests as shown in Fig. 6. The specimen was supported by the two symmetricaly placed roller supports near the ends and was loaded by the two symmetrically placed rollers near the middle. The rollers were set in cylindrical grooves in the loading and supporting blocks, the radius of the grooves being somewhat greater than the radius of the rollers so as to prevent longitudinal restraint. All tests were made on a cycle for which the stress in the bottom flange of the specimen varied from very near zero to a maximum tension.

The specimens for one group of flexural fatigue tests are given at the left in Table 1, and the results of the tests are given at the right of the same table. The specimens for the basic tests, series 44A, were standard 12-in., 31.8-lb. I-beams in the as-rolled condition. The value of $F_{2,000,000}$ for these beams, the average from three tests, was 32,000 lb. per sq. in. The value of $F_{100,000}$ was not determined because it exceeded the yield point of the steel.

The specimens for series 44Ba were similar 12-in., 31.8-lb. I-beams reinforced with full length cover plates attached with $\frac{3}{16}$-in. continuous fillet welds top and bottom, the top cover plate being 4 in. by 9/16 in. and the bottom cover plate being 6 in. by $\frac{3}{8}$ in. The values of the fatigue strength for these specimens were 38,900 and 21,800 lb. per sq. in. for $F_{100,000}$ and $F_{2,000,000}$, respectively. The value of $F_{2,000,000}$

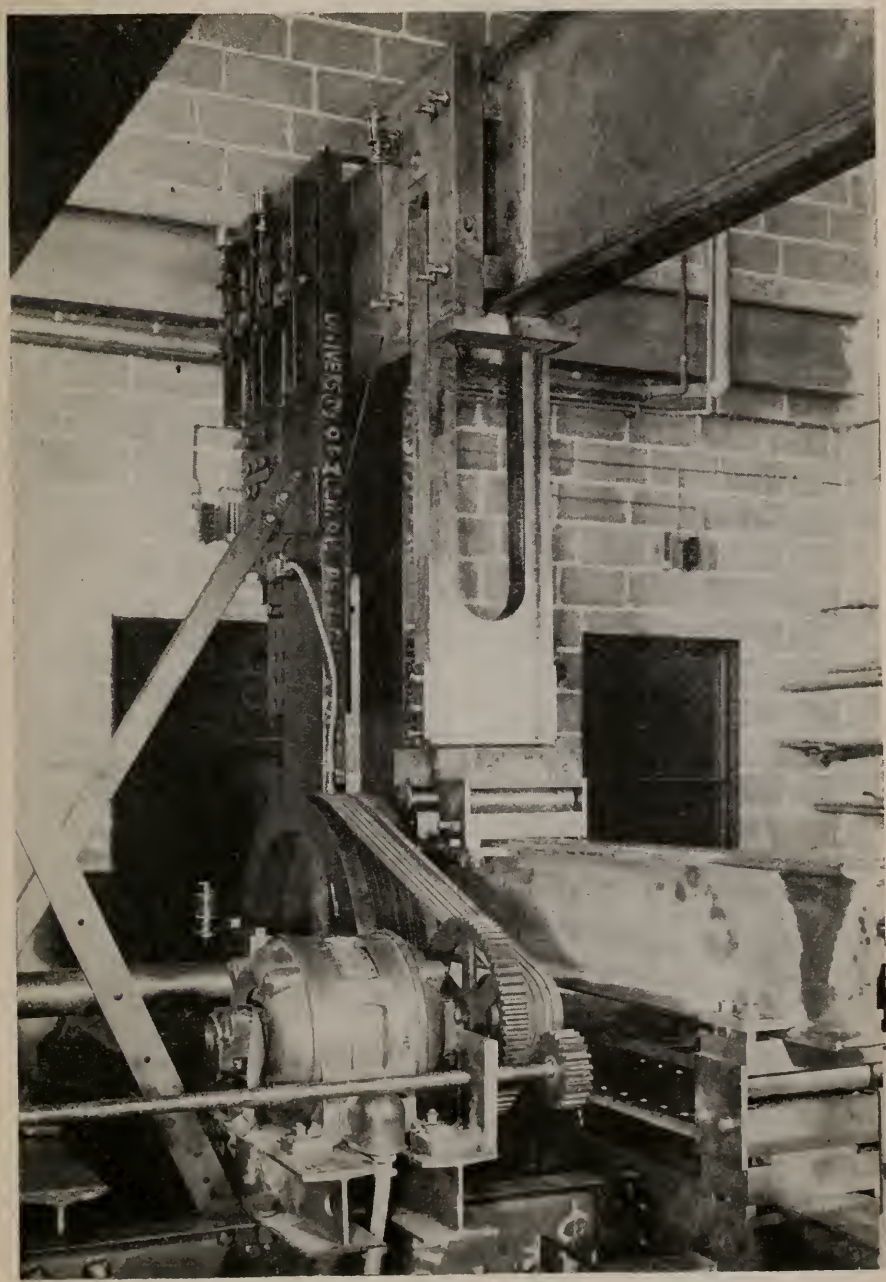


Fig. 6.—Flexural Fatigue Machine.

Table 1.—Flexural Fatigue Strength of Reinforced Rolled I-Beams

Test Series	Description of Test Specimen	Fatigue Strength Kips per Sq. In.	
		At 100,000 cycles	At 2,000,000 cycles
44A	Rolled beam	----	32.0
44Ba	Rolled beam with full length cover plates, 3/16-in. continuous fillet welds	38.9	21.8
44Bb	Rolled beam with full length cover plates, 3/16-in. intermittent fillet welds	40.0	15.5
44Ca	Rolled beam with partial length cover plates, 3/16-in. continuous fillet welds	18.0	7.8
44Ce	Rolled beam with partial length top cover plate and full length bottom cover plate, 3/16-in. intermittent fillet welds	21.6	8.0
44E	Rolled beam with partial length cover plates, 3/4-in. rivets. (All stress values based on gross section)	28.0	12.2
44Ja	Rolled beam with partial length cover plates, 9/16-in. continuous fillet welds	22.5	10.2
44Jb	Rolled beam with partial length cover plates, tapered in width, 3/16-in. continuous fillet welds	23.0	8.8
44Jc	Rolled beam with partial length cover plates, tapered in thickness, 3/16-in. continuous fillet welds	27.5	14.3

for the 44Ba series, beams reinforced with full length cover plates attached with $\frac{3}{16}$-in. continuous fillet welds, was only 68 percent of the value of $F_{2,000,000}$ for the 44A series, beams in the as-rolled condition. Adding the cover plates to the 12-in. rolled beams increased the section modulus from 36.0 in.^{3} to 60.4 in.^{3}, an increase of 68 percent. That is, attaching the full length cover plates with continuous $\frac{3}{16}$-in. fillet welds increased the section modulus 68 percent but reduced the value of $F_{2,000,000}$ from 32,000 to 21,800 lb. per sq. in. The ratio of the total fatigue strength of the I-beam as reinforced to the total fatigue strength of the same beam as-rolled was therefore $\frac{21,800 \times 60.4}{32,000 \times 36.0} = 1.14$, a rather small increase considering the expense involved.

The specimens for series 44Bb were 12-in., 31.8-lb. I-beams reinforced top and bottom with full length cover plates attached with intermittent $\frac{3}{16}$-in. fillet welds. The value of the fatigue strength of these beams were 40,000 and 15,500 lb. per sq. in. for $F_{100,000}$ and $F_{2,000,000}$, respectively. The value of $F_{100,000}$ was slightly more for these beams than for the beams of series 44Ba for which the fillet welds were continuous, but the value of $F_{2,000,000}$ was only 49 percent as great for 44Bb as for 44A,

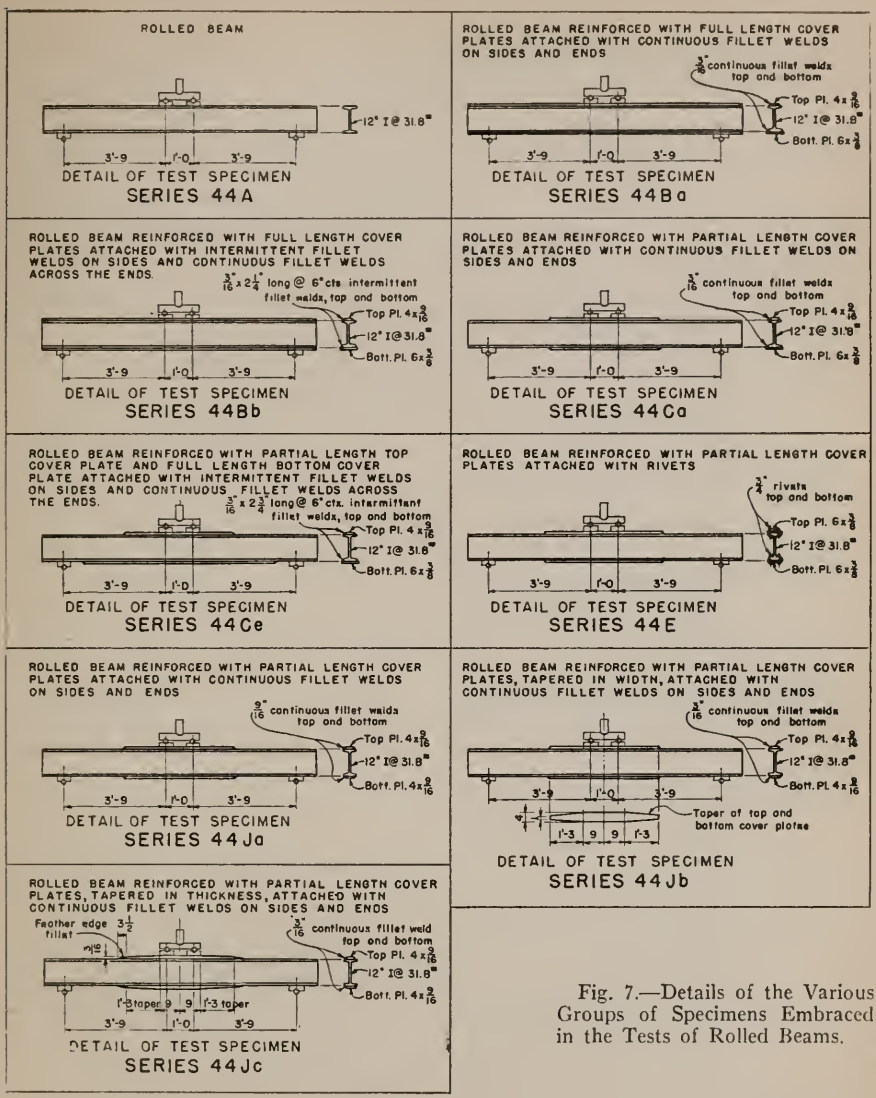


Fig. 7.—Details of the Various Groups of Specimens Embraced in the Tests of Rolled Beams.

and only 71 percent as great for 44Bb as for 44Ba. The total fatigue strength corresponding to failure at 2,000,000 cycles was actually less for these beams reinforced with full length cover plates attached with intermittent fillet welds than it was for the beams as-rolled.

The various series of Table 1 include an extensive variety of reinforced I-beams that were tested in fatigue and all of them except 44Ba series had a lower *total* fatigue strength than the 44A series which consisted of beams as-rolled. This comparison is made on the basis of the fatigue strength corresponding to failure at 2,000,000

TABLE 2.—FLEXURAL FATIGUE TESTS

Test Series	Description of Test Specimen	Fatigue Strength Lb. per sq. in. (000 omitted)		Static Strength Lb. per sq. in. (000 omitted)	
		At 100,000 cycles	At 2,000,000 cycles	Yield point	Ultimate
44Bd	Rolled beam with partial length cover plates. Bottom cover plates, corners clipped 45-deg., 3/16-in. continuous fillet welds	22.5	9.6	----	----
44Cb	Rolled beam with partial length cover plates., 5/16-in. intermittent fillet welds.*	18.0	7.9	----	39.3
44Cc	Rolled beam with partial length cover plates, 5/16-in. intermittent fillet welds.**	20.5	9.1	32.9	44.8
44Cd	Rolled beam with partial length top cover plate and full length bottom cover plate, 1/4-in. intermittent fillet weld	16.0	10.1	----	38.9
44Ga	Fabricated beam with flange plates attached to web with 1/8-in. continuous fillet weld	47.0	16.9	----	55.0
44Gb	Fabricated beam with flange plates attached to web with 3/16-in. continuous fillet weld	44.5	16.0	----	54.8
44Ma	Rolled beam with transverse cover plates attached to flanges with 1/4-in. transverse fillet weld	19.0	13.0	----	----
44Mb	Rolled beam with transverse cover plates attached to flanges with 1/4-in. longitudinal fillet weld	23.0	13.3	----	----
44Mc	Rolled beam with transverse cover plates attached to flanges with 3/4-in. rivets	25.8	14.1	----	----

* 6-in. by 3/8-in. bottom cover plate.
** 4-in. by 9/16-in. bottom cover plate.

cycles. And this is the basis on which it would seem that the comparison should be made since stringers are subjected to a larger number of cycles during their life. Only the beams reinforced with full length cover plates attached with continuous

fillet welds had a greater total fatigue strength than the beams as-rolled, and for these the difference was small. Moreover, the beams with partial length cover plates had a very much less total fatigue strength than the beams as-rolled. None of the expedients for eliminating the effect of the reduction in section at the ends of partial length cover plates was effective.

Values for $F_{2,000,000}$ of 8000 lb. per sq. in. or less for some reinforced beams is astounding. They indicate that reinforcing stringers with partial length cover plates is a positive and definite hazard and should not be practiced.

The results obtained for various expedients used to reduce the injurious effects of partial length cover plates are of interest. Tapering the end of the cover plate by reducing its width resulted in a value of $F_{2,000,000}$ of 8800 lb. per sq. in. Tapering the end by reducing the thickness resulted in a value of $F_{2,000,000}$ of 14,300 lb. per sq. in. These are comparable with the value of 32,000 lb. per sq. in. for $F_{2,000,000}$ obtained for the beams in the as-rolled condition.

Specimens consisting of rolled I-beams reinforced with partial length cover plates attached with ¾-in. rivets, series 44E, had a value of $F_{2,000,000}$ of 12,200 lb. per sq. in. of gross section. This corresponds to a value of 16,700 lb. per sq. in. of net section.

Only one specimen fabricated by attaching full length 6-in. by ⅜-in. cover plates to 12-in., 31.8-lb. rolled I-beams with ¾-in. rivets has been tested. The stress cycle for this test was from 0 to 18,000 lb. per sq. in. of gross section,* and failure occurred at 953,400 cycles. The corresponding value of $F_{2,000,000}$ is of the order of 16,000 lb. per sq. in. of the gross section or 22,000 lb. per sq. in. of the net section.

Table 2 shows the results of flexural fatigue tests of various types of specimens, most of which have a 12-in., 31.8-lb. rolled I-beam as a base. The first four series, all with partial length cover plates attached with various kinds of welds, have values of $F_{2,000,000}$ of 10,100 lb. per sq. in. or less. The next, series 44Ga and 44Gb, fabricated beams with flange plates attached to web plates with continuous fillet welds, have values of $F_{2,000,000}$ of 16,900 and 16,000 lb. per sq. in., respectively. The webs for these beams were 12-in. by $\frac{7}{16}$-in. plates and the flanges were 7-in. by ⅝-in. plates.

The specimens for the last three groups, series 44Ma, 44Mb, and 44Mc, represent rolled I-beams with short plates (intended to simulate gusset plates for stringer laterals) attached to the flanges in various ways. The plates were attached with ¼-in. transverse fillet welds for series 44Ma, and with ¼-in. longitudinal fillet welds for series 44Mb. The value of $F_{2,000,000}$ was 13,000 lb. per sq. in. for the former and 13,300 lb. per sq. in. for the latter. The plates for series 44Mc were attached to the flanges with ¾-in. rivets. The value of $F_{2,000,000}$ was 14,100 lb. per sq. in. based upon the gross section and 19,300 lb. per sq. in. based upon the net section.

Summary of Results

The tests reported in this paper appear to justify the following conclusions, all based upon the fatigue strength corresponding to failure at 2,000,000 cycles.

1. The three types of specimens planned to represent composite riveted and welded joints connecting the two parts of an eyebar that had been shortened by cutting out a piece and splicing, all had a very much lower fatigue strength than the original eyebar.

2. For specimens representing eyebars that had been shortened by heating and upsetting, the fatigue strengths of the shortened and the unshortened specimens were very nearly equal. This statement applies to both steel and wrought iron eyebars.

* This corresponds to 24,600 lb. per sq. in. of net section.

3. Adding butt straps attached with fillet welds across butt welds connecting plates, greatly reduced the fatigue strength of the joint.

4. The fatigue strength of the riveted splice of a girder web not designed to resist moment, was increased somewhat by connecting the splice plates to the girder web with fillet welds, the magnitude of the increase depending upon the thickness of the web plate and of the splice plates.

5. Specimens representing diagonal members of a truss reinforced with cover plates extending from and welded to the gusset plates at the two ends, had a much greater total fatigue strength than specimens representing similar members not reinforced.

6. The unit flexural fatigue strength of rolled 12-in., 31.8-lb. I-beams reinforced with full length cover plates attached with continuous $\frac{3}{16}$-in. fillet welds, was considerably less than the unit flexural fatigue strength of the same beams in the as-rolled condition. The reduction in the unit fatigue strength due to the welds offset almost completely the increase in the section modulus due to the addition of the cover plates, and the total fatigue strength was only slightly greater for the reinforced beams than it was for the beams that were not reinforced.

For rolled 12-in., 31.8-lb. I-beams reinforced with full length cover plates attached with $\frac{3}{16}$-in. intermittent fillet welds, the total fatigue strength was less for the reinforced beam than for the beam without reinforcement.

7. Attaching partial length cover plates to 12-in., 31.8-lb. I-beams, either by welding or riveting, greatly reduced the total fatigue strength of the beams and should not be permitted. Various expedients for reducing the stress-raising factor at the ends of the partial length cover plates were ineffective.

8. Attaching small plates to the bottom flange of rolled 12-in., 31.8-lb. I-beams, plates such as are used as gusset plates for stringer laterals, greatly reduced the fatigue strength of the beams. This was true for plates attached with (1) transverse fillet welds, (2) longitudinal fillet welds, and (3) $\frac{3}{4}$-in. rivets.

Chairman Bernhardt: On behalf of Committee 15 and this Association, I can't help but ask the question, what would this Association and particularly Committee 15 do without men like Professor Wilson in investigations of this kind? In fact, this one has been under way for eight years, and it is not yet complete. On top of that, we have coming up a parallel investigation on riveted joints.

Some years ago he spent five years finding out what was wrong with our rolling lift bridges, and that was also of great value to this Association.

We thank you, Professor Wilson, for your fine work and your fine address today.

That completes the report of Committee 15.

President Miller: Mr. Bernhardt, it is my understanding that you are now retiring as chairman of the Committee on Iron and Steel Structures after a service of five years. I want to thank you for your able leadership and the valuable work that this committee has done.

The committee is now excused with the thanks of the Association.

Committee on Waterproofing

(For Report, see pp. 250-252.)

(President Miller presiding)

Chairman J. A. Lahmer (Missouri Pacific): The first part of our report relates to revision of the Manual, which consists of new definitions, in some cases, for those in the Glossary, and one or two eliminations.

(He read the report on Assignment 1.)

Chairman Lahmer: The remaining change in the Manual is to eliminate the emergency provision which was adopted in December 1942, and consisted of abatement of some of the requirements for asphalt. Since the reason for which this emergency provision was adopted has passed, we wish to withdraw it from the Manual.

I move that the proposed changes in the Manual be adopted.

(The motion was seconded, put to a vote and carried.)

Chairman Lahmer: We now turn to the assignment entitled: Waterproofing of railway structures. This committee, in the past, has from time to time revised and extended the Specifications for Waterproofing of Railway Structures and, in a way, we have reached the end of the cycle. We have a specification which, according to all reports, gives us satisfactory material and workmanship.

However, some changes have taken place from time to time in manufacturing processes and in materials available, and we have received a number of suggestions from producers of bitumens regarding changes which they think would not in any way diminish the effectiveness of the material but would widen the competition. In short, I think that they would like, as nearly as possible, to have us purchase material from their stock rather than a special processed material which the present specifications call for, being based upon Mexican crude.

These suggestions may have merit but to determine the merits, further tests should be made. In the last two years, conditions have not been such that tests could be undertaken.

However, we have a final report by a subcommittee on some tests that have been made in the last few years under the direction of this committee for the purpose of determining the characteristics of materials that are available in the market which either comply with out specifications or in the minds of the producers would very nearly do so.

I will ask Mr. Robinson, the chairman of the subcommittee, to report on that assignment.

(G. E. Robinson, New York Central, read the report on assignment 2.)

Chairman Lahmer: In concluding the report of this committee, we wish to record our appreciation of the hearty cooperation and assistance we have received from time to time from the producers, particularly from their technological and research departments. We are also thankful for the help that we received from the various railroads that have cooperated in our investigations.

That is the end of the committee's report.

President Miller: Before excusing the Committee on Waterproofing from the rostrum, I wish to direct your attention to the fact that Mr. Lahmer has directed the work of the committee as its chairman since its organization in 1932 and is now retiring after 14 years of enthusiastic and conscientious effort.

Mr. Lahmer, we are very much indebted to you, and it is my sincere hope that the committee will continue to receive the benefit of your advice and counsel. Your committee is now excused with the thanks of the Association. (Applause)

Discussion on Impact and Bridge Stresses

(For Report, see pp. 247–249.)

(President Miller presiding)

Chairman C. H. Sandberg (Atchison, Topeka & Santa Fe): Before reporting on our committee work, we would like to pause and pay tribute to the former chairman of this committee, J. B. Hunley, who died March 2. We all knew him as an active and hard working member of this Association. Mr. Hunley did a great deal of work on impact in railroad bridges, and wrote a voluminous report on this subject which was published by the Association in Bulletin 380. Mr. Hunley was known as an authority on impact on steel railroad bridges. We on the committee will greatly miss his counsel and friendship.

Your committee has eight subjects. On subjects 5, 6, and 7 we have no report. On the other five assignments we are reporting progress. I shall read the reports on these five assignments.

(Chairman Sandberg then read the reports on assignments 1, 2, 3, 4 and 8.)

Chairman Sandberg: As noted by the president in his address on Tuesday, your Committee on Impact is one of the committees that has received appropriations to help carry out its investigations and research. The field testing is handled by the staff of the research engineer, Mr. G. M. Magee, with Mr. E. J. Ruble, structural engineer, in direct charge. Some of the test work on bridges is done at the request of individual railroads and at their expense. Some of the data collected in making these bridge tests for various railroads are used to advantage in our impact studies. During the last year the only tests made directly for the Impact committee were the tests on the 110-ft. through girder and the 47-ft. deck girder on the Milwaukee Railroad and mentioned in our report on Assignment 2.

Last year we presented a final report on impact on short span bridges. This report has been under consideration by Committee 15—Iron and Steel Structures, and the subcommittee handling this assignment has recommended a revision in the specifications to permit the use of lower impact for short spans, based on the findings of our tests. We understand some railroads have already used lower impacts in the design of short spans, in line with our findings.

During the past two years considerable time has been spent in the field measuring the strains in truss spans for individual railroads, at their expense. Several of these bridges were so located that the strains in the various members could be measured under single or double-headed test trains at speeds ranging from 5 mph. up to or above the critical speed for the bridge. The following summary of these results of stresses in truss spans may be of interest:

1. The impact in floor-beam hangers is about the same as that recorded in short beam spans, but the bending stresses resulting from floor-beam and stringer deflections are about as great as the combined static live load plus impact stresses.

2. The recorded static stresses in some truss members are as much as 30 percent greater than the calculated stresses, while in other members the static stresses are appreciably lower. Usually the static stresses in the lower chords of through spans are reduced by stringer action while the upper chord stresses are increased.

3. The impacts in truss spans are greater than the present AREA design impact allowance. The impacts reach a maximum at the critical speed and then become smaller with a further increase in speed.

4. There is considerable variation in the stresses in the eyebars of any one member. It has been found that one eyebar of a two-bar member carries as much as 97 percent of the total live load in the member.

The work of the committee and test force is now being concentrated on impact in girder spans. Arrangements have been made to test several such spans this year. It is our hope to make the next a final report on this subject.

This concludes the report of your committee.

(Vice-President Akers presiding)

Vice-President Akers: This committee is carrying on some exceedingly valuable work in the interest of more accurate and economical design of railway bridges. It is now excused with the thanks and appreciation of the Association. (Applause)

Discussion on Records and Accounts

(For Report, see pp. 253–315.)

(President Miller presiding)

Chairman H. L. Restall (Boston & Maine): During the two years that have elapsed since your committee has reported to the convention, there have been numerous important developments in the requirements by the Interstate Commerce Commission affecting railway engineers in general.

Realizing the necessity of progressing these subjects, we have concentrated upon them to the exclusion of some of the general assignments, which accounts for the appearance of the comment "no report" regarding several of our subjects. We have attempted to point out the current uses to which federal valuation has been put in arriving at a depreciation base, both current and for past accrued, also as a direct application to the carrier's books in current accounting and also for income taxes.

Engineers responsible for the maintenance of way accounts have already felt the effect of the charges for current roadway depreciation in their allowances. We have realized that they are in the form of fixed charges against the future, and, that with the changing economic conditions it was of paramount importance that the subject be given our undivided attention in order that we might convey to railway engineers in general the vital effect of this subject in their budgets.

As the result of our studies, we realize that these subjects have long since entered a specialized field, requiring constant application and research in order to keep abreast of the changes and adequately to protect the individual carrier's position at all times.

In order that this work may be carried on efficiently, we urge that all railway engineers become conversant with depreciation and its allied subjects. In order that those responsible for the details may have at their command all of your experience and judgment and, in particular, your advice on a subject involving such vast sums of money, we will now proceed with the report of the individual subcommittees, and I introduce Mr. Field, chairman of subcommittee 1—Revision of Manual.

D. E. Field (Columbus & Greenville): Since the reprinting of Chapter 11 of the Manual, the activities of this committee have been more or less restricted. However, it is the recommendation that those parts of the original chapter withheld from that printing be given further study and either revised or eliminated, in conformity with present accepted practice.

Our secretary, Mr. Lacher, has asked this committee to review the glossary of the Manual and submit recommendations for changes or deletions before the reprinting of the Manual as a whole. Your committee recommends that the subject be continued. Even the most casual review of this committee's part of the glossary demonstrates that this will require a considerable study.

Chairman Restall: The next subcommittee—Valuation and depreciation. In the absence of Mr. Baldwin, chairman of the subcommittee, the report will be rendered by Mr. Bolin.

W. C. Bolin (Baltimore & Ohio Chicago Terminal): The report of your subcommittee deals first with valuation and second with depreciation.

When the Valuation Act was passed in 1913 providing for the federal valuation of railroads, its greatest use was thought to be for rate-making purposes. Today rate making seems to be one of the lesser uses of the valuation reports, records and findings.

In its report under the heading of Property Records and Reports, the committee points out the variety of and the important uses made by the carriers of their valuation records. The committee likewise calls attention to the further reduced appropriation for the Bureau of Valuation of the Interstate Commerce Commission. In order that the reports and data furnished by the carriers may be processed and the results made available, it is essential that the bureau's forces be maintained at a sufficient size. It would seem to devolve on us to urge that a careful investigation should be made before the bureau's forces are reduced to the point of wholly destroying their effectiveness.

Under the heading of Assignment 6 (c)—Depreciation—the committee has produced a joint report prepared by a committee of accounting officers and some of its membership entitled Trends in Depreciation Practices. The report endeavors to give a perspective of the current trend of thought on the subject of depreciation.

It has become increasingly apparent that regulatory agencies, tax bodies, engineering associations and corporate officers have been giving intensive study to the question of proper rates and adequate reserves to cover the loss from depreciation of the property under their control. Each seeks in his own sphere to protect the interest he represents. This has meant that mortality studies, field inspections and engineering estimates will be prepared in order that the facts may be fully developed.

In these investigations the valuation records have furnished the basic data from which to conduct the study. The depreciation problem is a vital one, and your committee will continue its investigations and study of the subject as it pertains to railroad property.

The report is presented as information.

President Miller: It will be so accepted, Mr. Bolin.

Chairman Restall: The next committee subject is: Report upon changes in, revisions, and interpretations of ICC accounting classifications. Mr. Barnes, the committee subchairman will give this report.

H. D. Barnes (Chicago & North Western): In presenting the subcommittee report two years ago I indicated that the number of changes in the accounting classifications seemed to be decreasing. This trend has continued through 1944 and 1945 but it still is not clear whether we are reaching a static condition or this is a calm preceding a storm. Several proposed changes which have been postponed for the duration of the war can be expected to be revived in the near future.

As in previous years, our report has been prepared to show the proposed and actual changes made during the year that are of interest to engineers. The first part

contains a list of the proposed accounting rulings or orders submitted to Mr. Bunnell, vice-president, AAR, by the ICC Bureau of Accounts, which have been reviewed by your committee. This is followed by a list of the orders modifying the accounting classifications and accounting rulings or interpretations issued by the commission during the year.

It may be of interest to note that the hearings before the commission with respect to the accounting for driving posts to arrest water pockets and mud heaves, and for pressure grouting to stabilize roadbeds, are now in progress in Washington.

The ICC Bureau of Accounts has recently revived the proposal to require solvent railroads to restate their property accounts to reflect original cost or estimated original cost as determined by the Bureau of Valuation and to set up depreciation reserves for depreciable road property as now required for reorganized carriers and in the case of mergers and acquisitions.

This report is submitted as information with the recommendation that the subject be continued.

President Miller: It will be so received.

Chairman Restall: The next committee subject is: Methods for avoiding duplication of reports and for simplifying and coordinating work under the requirements of the ICC and other public authorities.

In the absence of Mr. Knowles, the subcommittee chairman, I would like to call your attention to the substance of this committee's report. For several years past a joint committee comprising members of the divisions of the AAR, including the AREA, have been giving serious study to this subject. Its report has been completed. It is preliminary in scope but marks the beginning of a program to do something about the volume of paper work necessary to satisfy public bodies and regulatory agencies.

The report was received as information by the general committee of the Accounting Division and Operating-Transportation Division, respectively, and was distributed to their membership.

It seemed to your committee that, as engineers, we have a large stake in this program, all of us are concerned with budgetary procedure and with the preparation of analyses of statistical information and, in particular, as it relates to operating performance. There is much in the report for the engineer, as many of these reports originate on the divisions before being consolidated as a part of the system figures and any savings in paper work are immediately felt at the source, namely the division office.

For this reason, it seems to your committee that the entire membership should have the opportunity of reviewing this report and offering its criticisms and suggestions. We recommend it for your serious attention.

This concludes the report of the committee.

President Miller: Gentlemen, this committee is not only a hard-working committee but it works on matters that are of intense importance to all railroads, and if no other reports are read by some division engineers and district engineers and chief engineers, the reports usually made by this committee ought to be read.

Mr. Restall, before dismissing the committee with the thanks of the Association, I wish to congratulate you on the work which the committee has done during your three years as chairman. You and your committee have done a magnificent job. We appreciate your service to the Association. The committee is dismissed. (Applause)

MONOGRAPHS

Determination of Lateral Outward Forces on Each Rail of a Turnout

Studies of a No. 14 Turnout in a Lead Track of the Chicago & North Western Passenger Terminal at Chicago

Foreword

Several railways have had difficulty in holding rail to gage on turnouts with the new heavy 4–6–4 and 4–8–4 type locomotives. This investigation was conducted on the Chicago & North Western Railway to determine the lateral outward thrusts exerted on the rails of a turnout in the approach to the passenger terminal at Chicago, where several spikes had recently been sheared off along the outside of the inner rail.

The tests were conducted by the Engineering Division research staff with funds provided by the Association of American Railroads and with locomotives and facilities furnished by the C. & N. W. Ry. Randon Ferguson, electrical engineer, and M. F. Smucker, assistant electrical engineer, conducted the field tests and H. E. Durham, track engineer, analyzed the data and prepared the report under the general direction of W. I. Cantley, mechanical engineer, and G. M. Magee, research engineer. E. H. Weston of the C. & N. W. Ry. mechanical department rendered valuable assistance in conducting the tests.

The Test Track

The location selected for the test was Turnout No. 59 of the Clinton Street interlocking tower about one-half mile from the Madison Street passenger terminal. This turnout is located in track No. 3 of a six-track passenger lead to the station and forms part of a crossover between tracks 3 and 2. This is a westbound track and is built on a 7-deg. 30-min. curve. The turnout breaks out on the inside of the curve and has a No. 14 railbound manganese frog, 21 ft., 9 in. in length, curved switch points 25 ft. in length, and an actual lead of 116.6 ft. The turnout was laid with new 112-lb. RE rail in 1944, four-hole joint bars and double-shoulder tie plates, 7¾ in. wide by 11 in. long. The switch ties were in good condition except for some splitting. Fig. 1 shows in detail the layout back of the heel of switch and the location of the weigh bars. The photograph in Fig. 2 shows the track construction that existed during the test. Fig. 1 shows some of the double-shoulder tie plates near the test ties which were replaced with the twin tie plates, without shoulders, in order to provide the same track construction that existed at the time some of the spikes along the inner rail were sheared off. The track is on a 15-ft. fill between retaining walls, at approximately level grade, and ballasted with crushed rock to a depth of 12 in. or more below the ties. The gage rods on the turnout rails, shown in Fig. 2, were released while testing was in progress. Also in Fig. 2 it will be observed that only one spike was holding the gage of each rail at the location of the twin tie plates.

On March 28, 1945, at the end of the test runs with the elevation lowered to 1 in., the turnout was checked for alinement, gage and elevation. Middle ordinates from 20-ft. chords were measured along the two outer rails. By a graphical method it was found that the curve of the outer closure rail between the heel of switch and the toe of frog

Bulletin 454, September–October 1945.

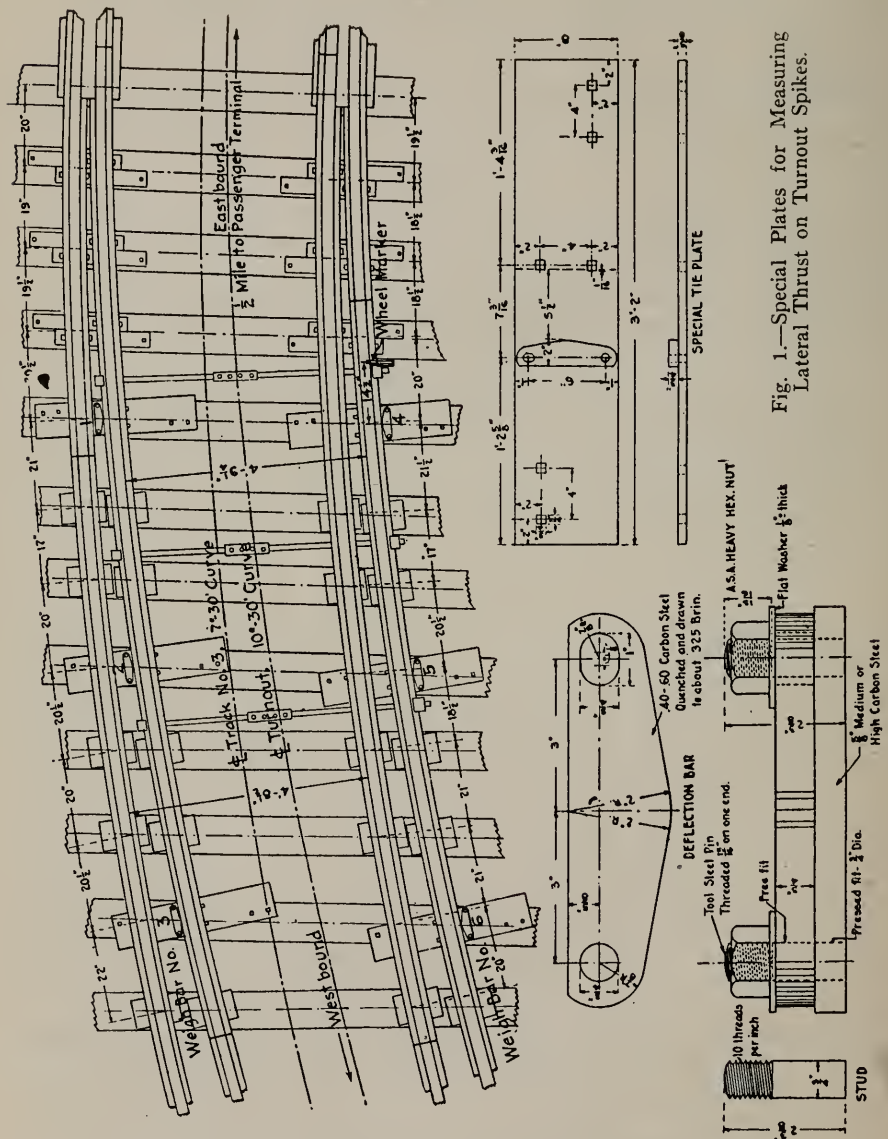


Fig. 1.—Special Plates for Measuring Lateral Thrust on Turnout Spikes.

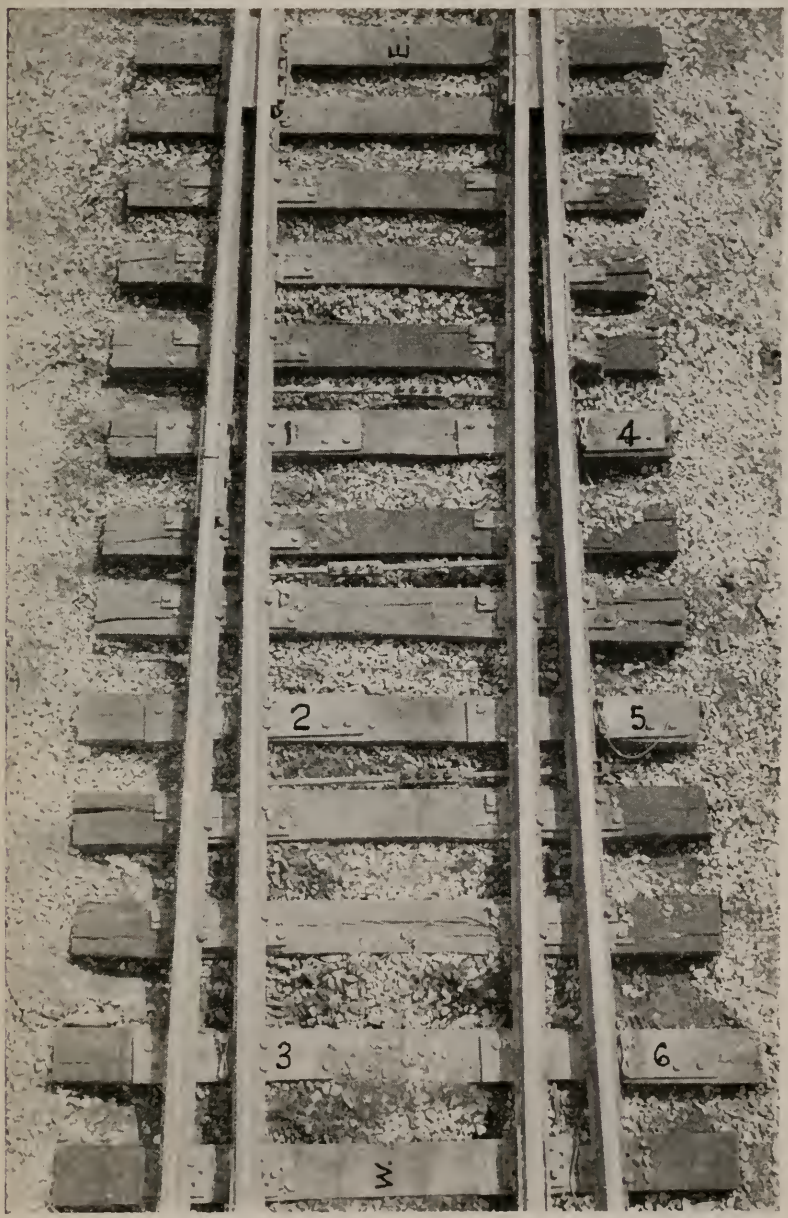


Fig. 2.—View of Test Location Showing Position of Weigh Bars 1 to 6, Inclusive.

Fig. 3.—View of Weigh Bar in the Track.

averaged 10 deg. 30 min. The deviation of the outer rail of the turnout from this curve was less than 1 in. The track gage was standard at the points of switch and frog, but varied from $\frac{1}{16}$ in. tight to $\frac{3}{16}$ in. wide between these points. It was $\frac{1}{2}$ in. wide at the weigh bar locations and averaged $\frac{1}{4}$ in. wide through the turnout.

Stress Recording Equipment

In Figs. 1 and 2 the location of the weigh bars for each rail is shown on every third tie beginning with the fifth tie from the heel of switch. Fig. 3 is a view of one of the weigh bars in the track and shows the position of the wire resistance strain gage, $\frac{1}{2}$ in. in length. Fig. 4 shows the electronic recording apparatus located in the Clinton Street tower about 75 ft. from the test track. The recording apparatus, consisting principally of a power supply, a six-channel wire gage amplifier, and a 12-element oscillograph, was the same as that used with the wire resistance gages in the Lathrop tests of 1944 on the Chicago, Burlington & Quincy Railroad (see Proceedings Vol. 46, 1945, page 692). From the strain recorded on the oscillograms the flexural unit stress in each of the six weigh bars was determined and this was converted to lateral force in pounds from the flexural formula, the lateral force being one-third of the unit bending stress in the extreme fiber of the weigh bar. One of these bars was tested in a compression-tension machine in the civil engineering laboratory of the Northwestern Technological Institute, Evanston, Ill., and the computed ratio of load to extreme fiber stress was found to be almost exact.

Weigh bar gages 1, 2, and 3 measured the outward lateral force on the outer rail at the three locations and gages 4, 5, and 6 registered the corresponding forces on the inner rail. The inward forces on the rails were not measured. Obviously, a portion of the lateral force transmitted from the wheels to the rail is dissipated by the friction

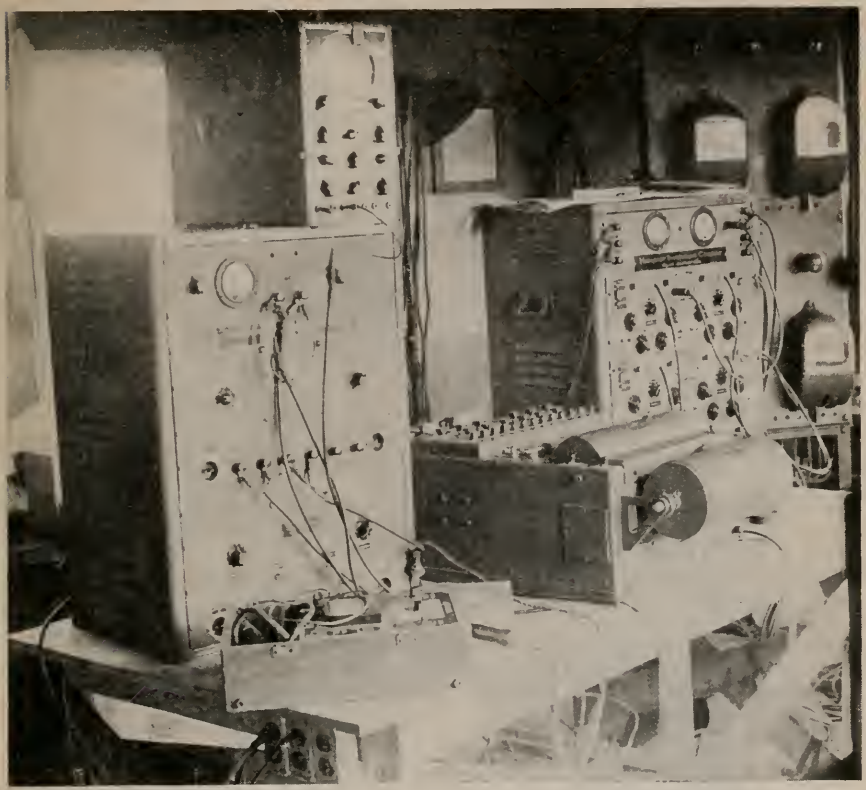
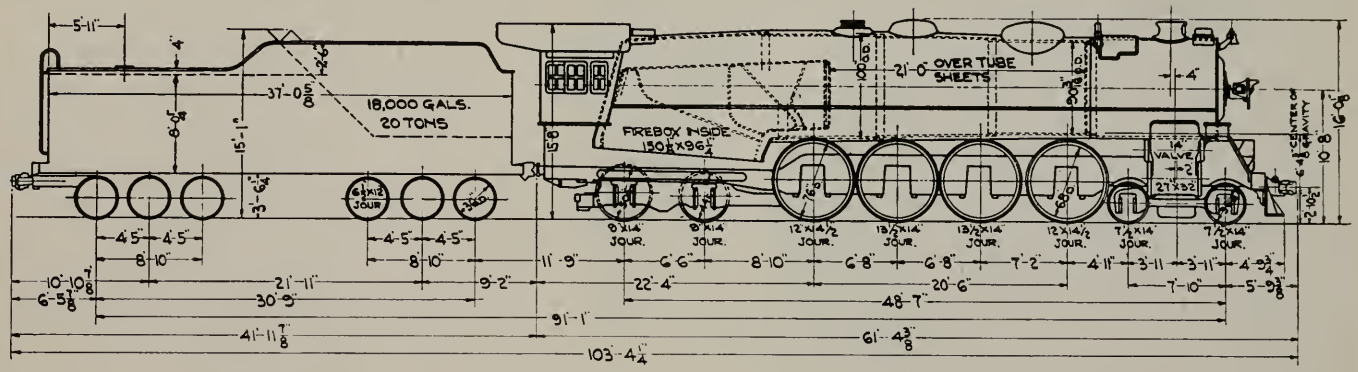


Fig. 4.—Wire Resistance Strain Gage Recording Apparatus in the Clinton Street Interlocking Tower (Left to Right: Power Unit, Oscillograph and Control Unit).

between the rail base and the tie plates and does not reach the weigh bars. However, the lateral forces measured are actually those that were exerted on the spikes by the rail base.

Tests of March 1945

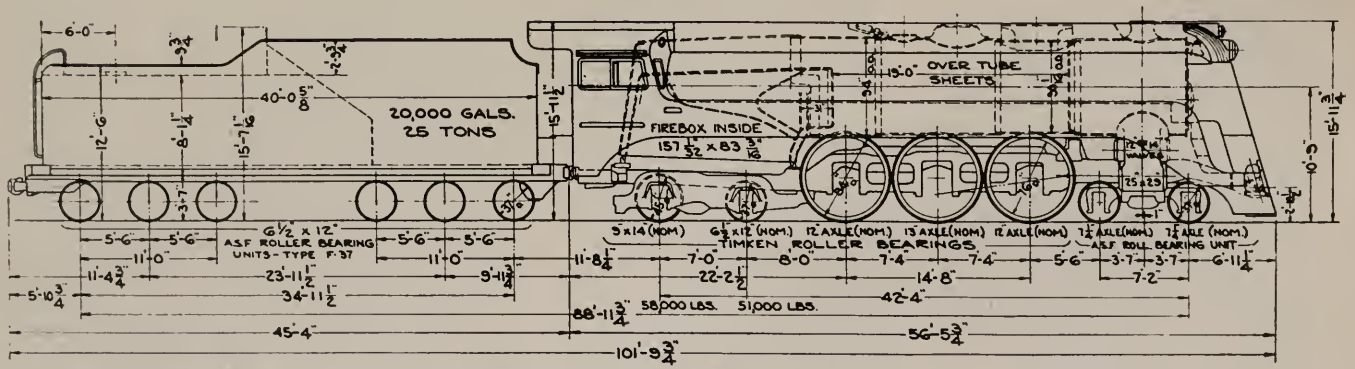
The test track carried approximately 50 passenger trains daily. A majority of the records was taken in the evenings when through passenger trains hauled by C. & N. W. classes H (4–8–4) and E–4 (4–6–4) locomotives passed over the test track. These trains would first back through the turnout in an easterly direction and push approximately 15 empty passenger cars to the passenger terminal. After loading, the same trains would head out of the terminal and make a facing point movement over the test track at speeds usually below 15 mph. Locomotive diagrams of these two classes of power are shown in Figs. 5 and 6. Both classes of locomotives had the 4-wheel General Steel Castings Co. engine truck and the Delta type 4-wheel trailing truck. The class H (4–8–4) locomotives had 30 and 15 percent constant resistance in their leading and trailing trucks, respectively, and the trucks of the class E–4 (4–6–4) locomotives were arranged for 33 and 15 percent constant resistance in the leading and trailing trucks, respectively.



STEAM PRESSURE	275 LBS.	FACTOR OF ADHESION	BOOSTER	5.24	WEIGHTS	
TUBES	12-2"		ENG. DRIVERS	4.01	TRUCK LOADED	87,000 LBS.
FLUES	214-3½"	WIDTH OVER CYLINDERS		10'-11"	TRAILER "	123,000 LBS
GRATE AREA	100 SQ.FT	MINIMUM CURVE	20° OR 288 FT. R.		DRIVERS "	288,000 LBS.
STOKER	STANDARD, SIMPLEX MODIFIED TYPE "B"	HEATING SURFACE			ENGINE "	498,000 LBS.
AIR PUMP	2-8½" CROSS-COMP. WESTINGHOUSE	TUBES	131.3	SQ. FT.	TENDER "	320,000 LBS.
FEED WATER HEATER	WORTHINGTON TYPE "S S"	FLUES	4098.0	SQ. FT.	ENG. & TEN. "	818,000 LBS.
VALVE GEAR (BAKER 3001-3005 INC.)	WAL. 3006-3035 INC)	ARCH TUBES	20.5	SQ. FT.	ENGINE LIGHT	446,000 LBS.
BOOSTER	FRANKLIN	SYPHONS	103.5	SQ. FT.	TENDER "	135,000 LBS.
TRACTIVE POWER ENGINE	71,800 LBS.	FIREBOX & COMB. CHAMBER	394.0	SQ. FT.	ENG. & TEN. "	581,000 LBS.
TRACTIVE POWER BOOSTER	12,400 LBS.	TOTAL	4747.3	SQ. FT.		
TRACTIVE POWER TOTAL	84,200 LBS.	SUPERHEATER	2357.0	SQ. FT.		

Fig. 5.—Class H Engines 3001–3035, Inclusive, (4–8–4 Type.)

CLASS E-4 ENGINES 4001-4009 INC.
(4-6-4 TYPE)



STEAM PRESSURE	300 LBS.
TUBES	8 - 2"
FLUES	196 - 3 1/2"
GRATE AREA	90.7 SQ.FT.
STOKER	STANDARD TYPE BK.
COAL PUSHER - SLOPE SHEET TYPE D-A	
LOW WATER ALARM - BARCO TYPE F-3A	
VALVE GEAR	BAKER
TRACTIVE POWER	55,000 LBS.
FACTOR OF ADHESION	3.93
WIDTH OVER STREAMLINING	10'-10 3/4"
MINIMUM CURVE	20° OR 288 FT. R

HEATING SURFACE	
TUBES	79.0 SQ.FT.
FLUES	3393.0 SQ.FT.
ARCH TUBES	21.0 SQ.FT.
SYPHONS	119.0 SQ.FT.
FIREBOX AND COMB. CHAMBER	367.0 SQ.FT.
TOTAL	3979.0 SQ.FT.
SUPERHEATER	1884.0 SQ.FT.

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WEIGHTS	
TRUCK LOADED	87,000 LBS.
TRAILER "	109,000 LBS.
DRIVERS "	216,000 LBS.
ENGINE "	412,000 LBS.
TENDER "	360,000 LBS.
ENG.&TEN. "	772,000 LBS.
ENGINE LIGHT	373,000 LBS.
TENDER "	150,000 LBS.
ENG.&TEN. "	523,000 LBS.

Fig. 6.—Class E–4 Engines 4001–4009, Inclusive, (4–6–4 Type).

The front drivers of the class H locomotives were equipped with lateral motion, the total pedestal play being 2 in. or 1 in. each way from the neutral position. All of the class H and E–4 locomotives had Franklin E–2 type radial buffers. All of the 4–6–4 type locomotives had roller bearings on all axles. With the exception of engine 3010 (4–8–4) with friction driving boxes and engine 3019 (4–8–4) with friction bearings on all axles, all of the class H (4–8–4) locomotives included in this test had roller bearings throughout. All of the locomotives tested had been out of the shop for a year or more and had more than the minimum lateral play, except that engines 4006 and 4008 (4–6–4) had been last shopped in February 1945 and were classed as being moderately stiff by the railway's mechanical department. In addition to the test runs made with regular trains, light engines 3010 (4–8–4) and 4003 (4–6–4) were assigned to the test crew for a few hours and several runs were made with each, backing up eastbound and heading through the turnout westbound. The sharpest curve over which the two classes of power can operate is 20 deg.

Discussion of the Test Data

Typical Oscillograph Record

In Fig. 7 a typical oscillogram of the weigh bar stress measurements is shown for one of the 4–6–4 type locomotives hauling 12 passenger cars at 10 mph. westbound through the turnout. The three upper traces indicate the strains measured in the three weigh bars along the outer rail of the turnout and the next three traces show the corresponding information for the inner rail. The bottom trace gives the wheel positions as the same pass over the six weigh bars. The dotted lines indicate the method used to read the weigh bar stresses for the first pilot on the outer rail and the main driver on the inner rail, which are the maximum values for the respective rails. Stress values for the other wheels are obtained in a similar manner. For convenience, the vertical scales are shown in pounds of lateral force exerted on the weigh bars by the locomotive. It will be of interest, in this connection, to refer to the upper lateral force diagram in Fig. 9-b for a translation of the oscillograph record in Fig. 7 for run 95. Fig. 9-b will be discussed later.

Test Runs and Track Conditions

From March 15 through March 30, 1945, oscillograph records were taken of 116 engine movements through the turnout. The first 70 test runs were made with the test track in its "original condition" with 1½ in. of elevation. The elevation was then reduced to 1 in. and test runs from 71 to 97, inclusive, were recorded. After restoring the elevation to 1½ in., runs 98 to 106, inclusive, were made. For the remainder of the test runs from 107 to 116, inclusive, the track was retained as in the preceding test series but graphite grease was applied between the rail base and the top of the weigh bar tie plates and the other tie plates throughout the test location and for three ties beyond the outer weigh-bar locations. In all cases the elevation was run out to 0.6 in. at the point of frog to accommodate another turnout located 22 ft. west of this frog point which diverged from track No. 3 on the outside of the curve. This test included 10 of the 4–8–4 locomotives and seven of the 4–6–4 type engines.

Lateral Force Diagrams for Class H Locomotive

Figs. 8-a and 8-b show seven lateral force diagrams for the 4–8–4 type locomotives hauling passenger cars. In Fig. 8-a there is a typical diagram for each of the four different movements through the turnout with the original track condition. In Fig. 8-b one diagram for a westbound forward movement is shown for each of the other three track conditions. The arrows at the wheels show the direction of the lateral force produced by

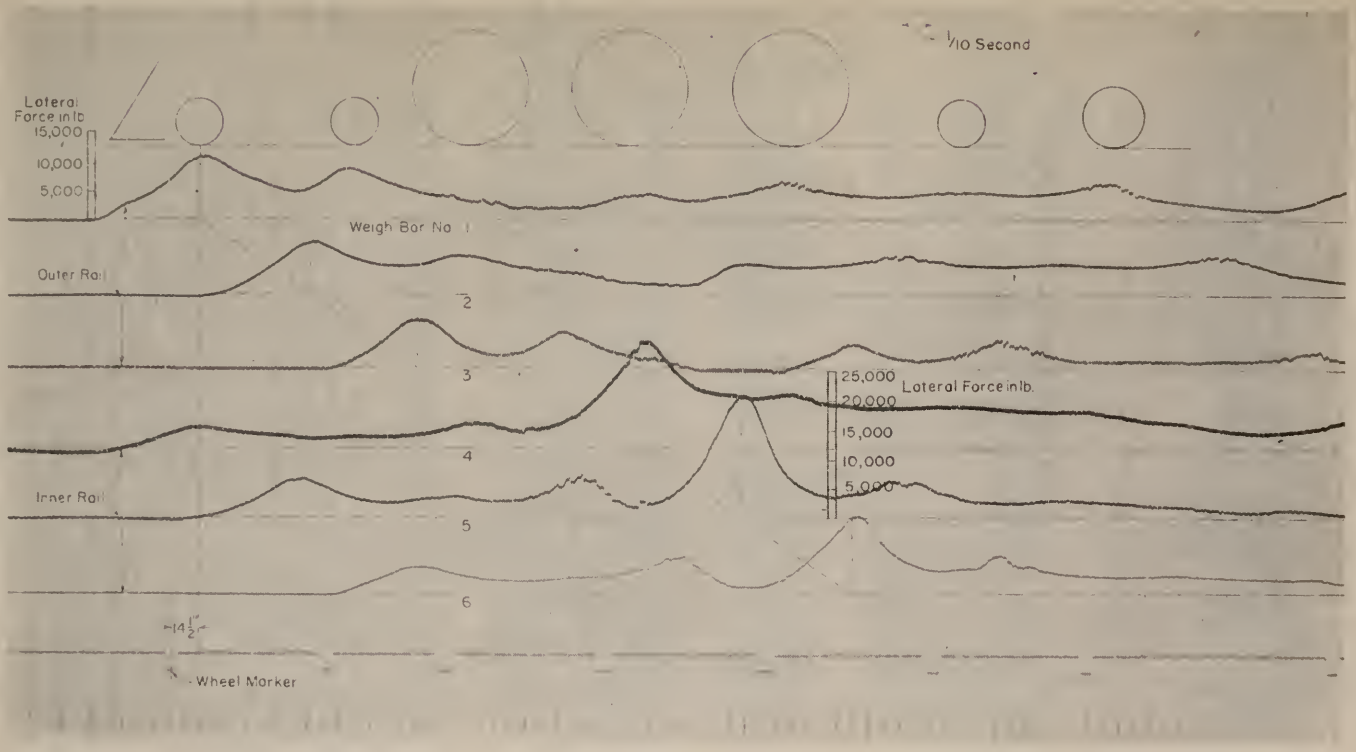

Fig. 7.—Record of Stresses Measured in the Weigh Bars. Run 95, Locomotive 4001 (4–6–4) Hauling 12 Cars at 10 mph. Westbound.

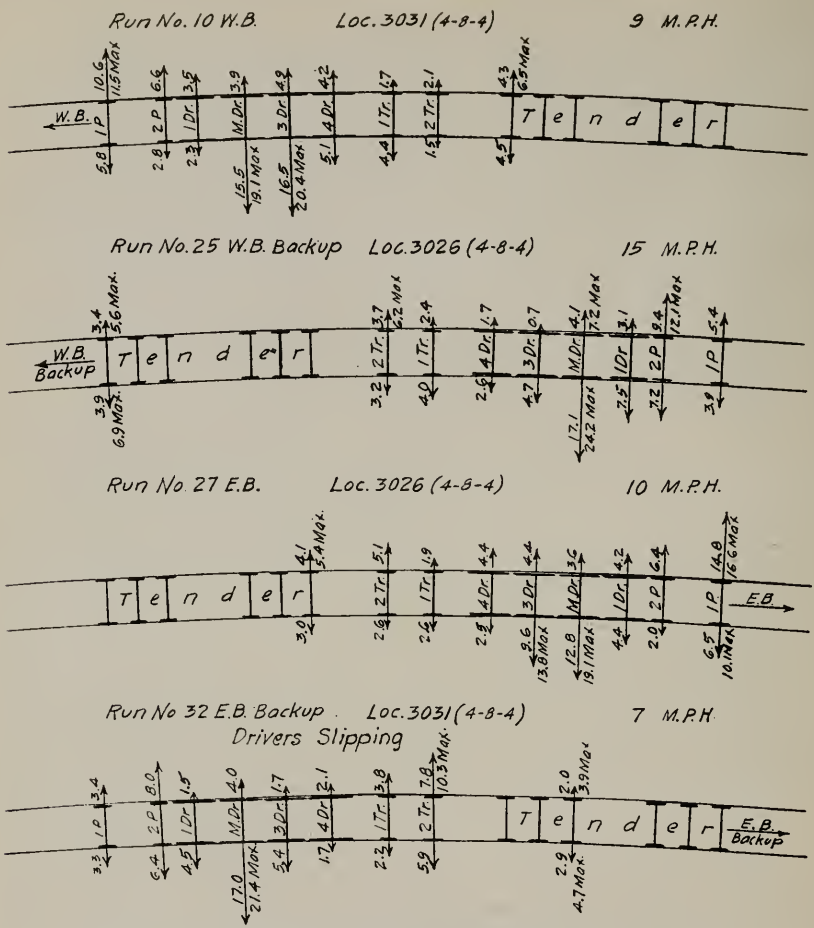

Fig. 8-a.—Lateral Force on Base of Rail in Thousands of Pounds, Original Track Condition.

the locomotive on the rail and the figures indicate the magnitude of the forces in units of 1000 lb. Each of the values shown, except those designated as maximum, is the average of the forces measured by the three weigh bars along one of the turnout rails as the wheel passed over the gage locations. The force marked maximum is the highest one of the three values. The force diagrams of the westbound forward movements (runs 10, 97, 106, and 116) reflect a very consistent pattern. The maximum lateral forces on the outer and inner rails occur at the first pilot and third or intermediate driver, respectively. The forces on the inner rail are approximately twice as large as those exerted on the outer rail. The pattern of forces for the eastbound forward movement (run 27) differs from westbound diagrams in that (1) the maximum force on the inner rail occurred under the main driver and (2) the forces on the outer rail at the first pilot were larger. The patterns of the back up movements in both directions (runs 25 and 32) are generally in agreement except the position of the maximum force on the outer rail is different. In run 25, westbound, it occurred under the second pilot and in run 32, east-

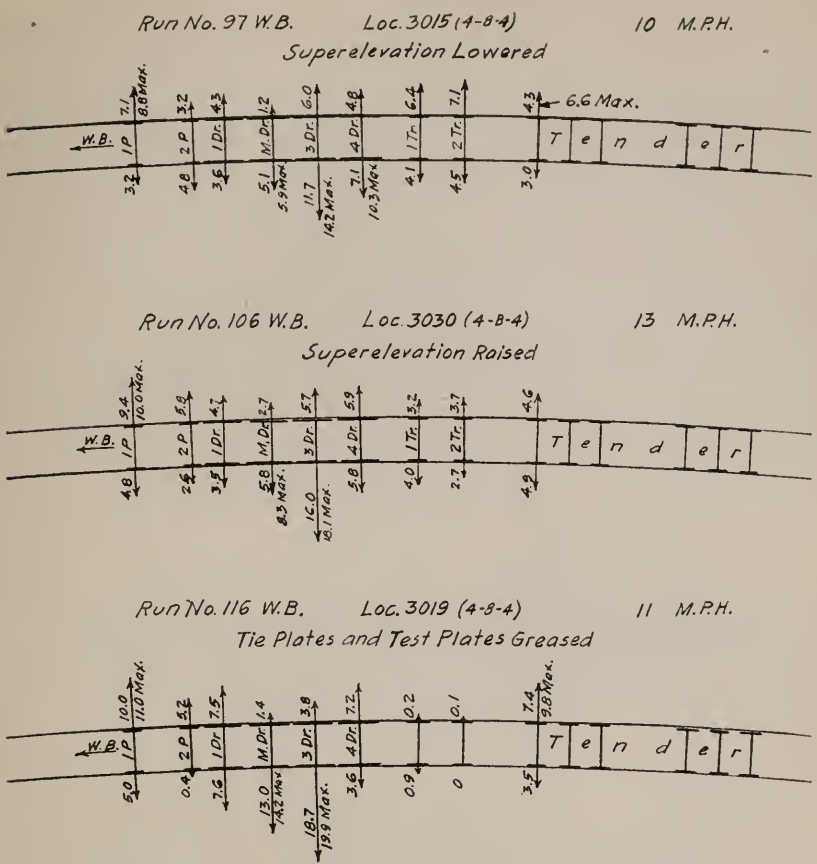

Fig. 8-b.—Lateral Force on Base of Rail in Thousands of Pounds.

bound, the larger forces were under the second trailer as well as the second pilot. Slipping of the drivers in run 32 did not affect the magnitude of the forces under the drivers to any appreciable extent. In the forward movements the outward thrust on the outer rail by the first tender wheel was generally somewhat smaller than under the first pilot; however, in other runs analyzed the two values were comparable in magnitude. Also in the forward movements the thrusts on each rail by the trailers were of moderate magnitude. Figs. 8-a and 8-b are not offered for the purpose of showing the variation in the lateral forces due to the changes in track conditions as different locomotives were used. Instead, they are merely illustrative of conditions observed. In some instances the test run selected showed high lateral forces.

Lateral Force Diagrams for Class E–4 Locomotives

Figs. 9-a and 9-b include six diagrams of lateral force exerted on the turnout rails by the 4–6–4 type locomotives and comprise a parallel exhibit to Figs. 8-a and 8-b. One westbound forward movement is shown for each of the four track conditions and, in addition, eastbound forward and back up movements for the original track condition are included. All of the forward movements have the same pattern of lateral forces with

the maximum thrusts occurring on the outer rail under the first pilot and on the inner rail under the main driver. In the eastbound back up movement, run 31 (Fig. 9-a), the larger forces on the outer rail occurred under the second trailer, leading tender axle, and the second pilot. The forces produced by the leading wheels of the tender trucks were comparable to those exerted on the corresponding rails by the locomotive. Run 42 (Fig. 9-a), a westbound forward movement with engine 4006, classed as being moderately stiff, was made on wet rail with the drivers slipping and produced the largest thrust on the inner rail of any of the runs made by the 4–6–4 type locomotives. A study of four runs made by the 4–6–4 type locomotives under normal conditions and another four runs with the drivers slipping, all with the track in its original condition with 1½ in. elevation, disclosed that the maximum thrusts on the outer rail by the first pilot were about the same. However, the mean maximum force exerted on the inner rail by the main driver increased from 12,600 lb. to 20,600 lb. when the drivers slipped. As in the case of the 4–8–4 locomotives, the forces from the trailers of the 4–6–4 locomotives were small when making forward movements. It will be observed in run 102, Fig. 9-b with engine 4008, classed as being moderately stiff, the thrust on the outer rail of the leading tender wheel is slightly larger than that recorded under the first pilot.

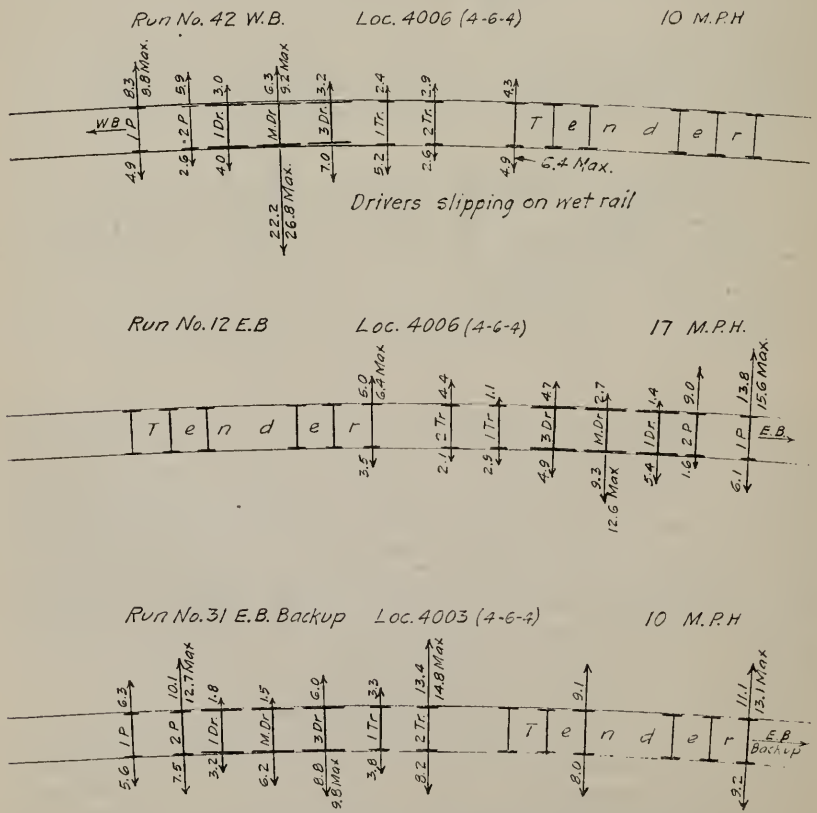

Fig. 9-a.—Lateral Force on Base of Rail in Thousands of Pounds, Original Track Condition.

Effect of Speed on the Lateral Thrust Against the Rails

During the test, engines No. 4003 (4–6–4) and No. 3010 (4–8–4) were made available for a few hours to carry out test runs running light and headed west. This afforded an excellent opportunity for examining the effect of speed on the lateral forces acting on each rail of the turnout. The results of this analysis are shown in Fig. 10. Only the maximum forces exerted on each rail are included in these graphs. Each group of three points plotted with the same symbol represents the successive values recorded by the three weigh bars on one of the rails in a run for the wheel, as indicated by the legend. In the upper portion of Fig. 10 there is a marked progressive reduction of the thrust on the inner rail as the speed of engine 4003 (4–6–4) varies from 3.4 to 22 mph. The thrust on the outer rail increased moderately with increasing speed. Although the two mean curves intersect at a speed of 12 mph., which is close to the equilibrium speed of the test track, the significance of this relation must be questioned because the mean curves in the lower part of Fig. 10 do not intersect at this speed. The forces plotted in

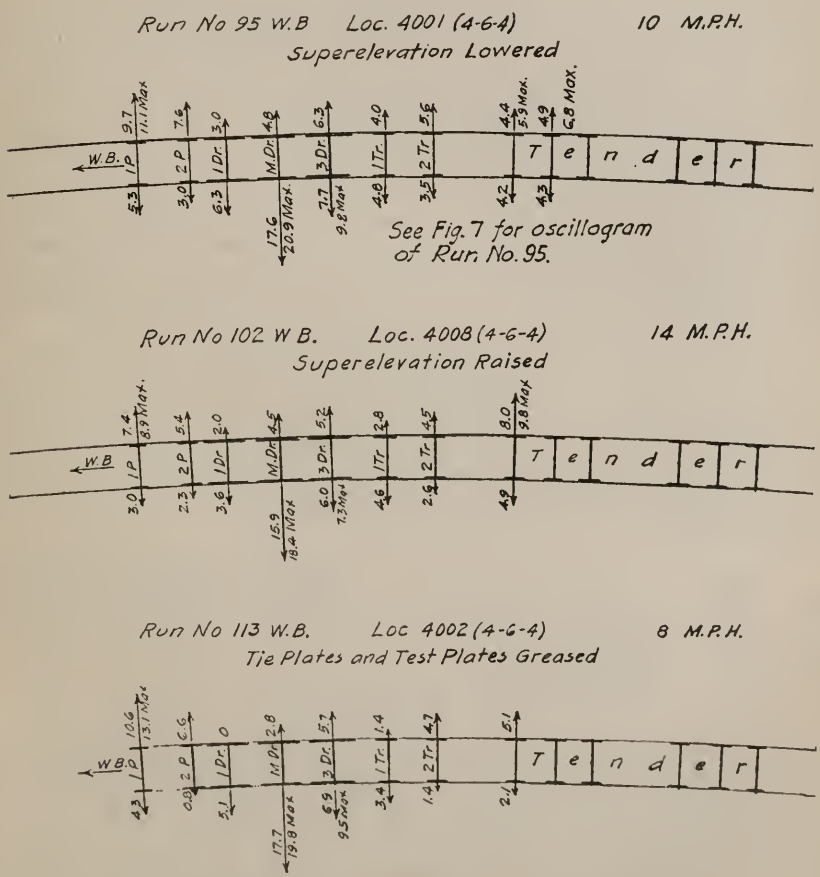

Fig. 9-b.—Lateral Force on Base of Rail in Thousands of Pounds.

the lower portion of the figure for engine 3010 (4–8–4) indicate the same corresponding tendencies as the curves in upper part of the figure, but to a lesser degree. The mean curves in Fig. 10 do show a logical relation between the lateral forces exerted on the rail and the speed of the locomotives.

Irregularity of the Lateral Forces

Figs. 11 and 12 are presented to show the irregularity in the magnitude of the maximum thrusts on each rail during the test period for several locomotives of each class of power. The data shown are for regular westbound trains hauling 11 to 17 passenger cars. Each point plotted is the average lateral force measured in a test run by the three weigh bars along one of the rails for the wheel indicated. In the upper portion of Fig. 11 for the 4–8–4 type locomotives the thrusts on the inner rail from the intermediate driver are plotted for seven locomotives in 14 runs. All of the values, except one, for the original track condition (elevation 1½ in.) were larger than those for the second track condition with the elevation reduced to 1 in. For the third track condition with the elevation restored to 1½ in. the forces increased in magnitude and were comparable with those measured in the original track condition. With the plates greased a further increase in thrust was noted on March 30. Engine 3026 ran on the 15th and 21st with the track in its original condition and the thrusts on the inner rail were about the same. This engine also ran on the 23rd and 27th with the track elevation decreased and these values were nearly equal but somewhat smaller than in the runs with the original track condition. The value for engine 3031 on the 23rd for the second track condition was considerably lower than on the 15th and 21st with the original track condition. There is an indication of a reduction in the forces on the inner rail when the elevation was reduced to 1 in. However, this may have been due to some change other than in the track, such as a difference in the drawbar pull, or the difference in the functioning of the radial buffer. In the lower part of Fig. 11 the trend of the forces on the outer rail is similar to those on the inner rail, but to a lesser extent. These variations are no more than would be expected in tests of this character.

In Fig. 12 for the 4–6–4 type locomotives the data are shown for 7 locomotives in 25 runs. In the upper portion of the figure the forces on the inner rail from the main driver display a wide scatter. A number of the higher forces occurred when the drivers were slipping on March 20. As an example of the variations of the lateral forces on the rail the performance of engine 4007 will be used as this locomotive made one run in each of the four track conditions without slipping its drivers. For convenience the results are tabulated below.

March	*Speed Mph.*	*Track Condition*	*Mean Maximum Lateral Force in 1000 Lb. Outer Rail*	*Inner Rail*	*Number of Passenger Cars Hauled*
20	9	Original	7.5	16.5	17
22	10	Elevation lowered	9.3	6.6	12
28	11	Elevation raised	6.4	13.5	12
30	12	Plates greased	9.9	13.9	16

It is evident that the abrupt drop in the force on the inner rail from March 20 to March 22 would not be caused solely by reducing the track elevation from 1½ in. to 1 in. The variations in the operation of the locomotive at slow speed apparently had a greater influence upon the lateral forces. Since all these runs were made by regular westbound trains there was no opportunity to obtain the usual cab data or observe such other conditions as whether sand was being used or the buffer faces were lubricated properly.

Wheel Flange Positions

Slow motion pictures were taken along the gage side of the inner turnout rail to record the flange position with respect to the rail. The camera was placed on a tie near weigh bar No. 6 and focused easterly to photograph the wheels and rail near weigh bar No. 5. The camera film drive was operated by means of an electro-magnetic trip controlled by the oscillograph operator. Enlargements of one film frame were made for each wheel and these flange position pictures are presented in Fig. 13 for locomotive 3029

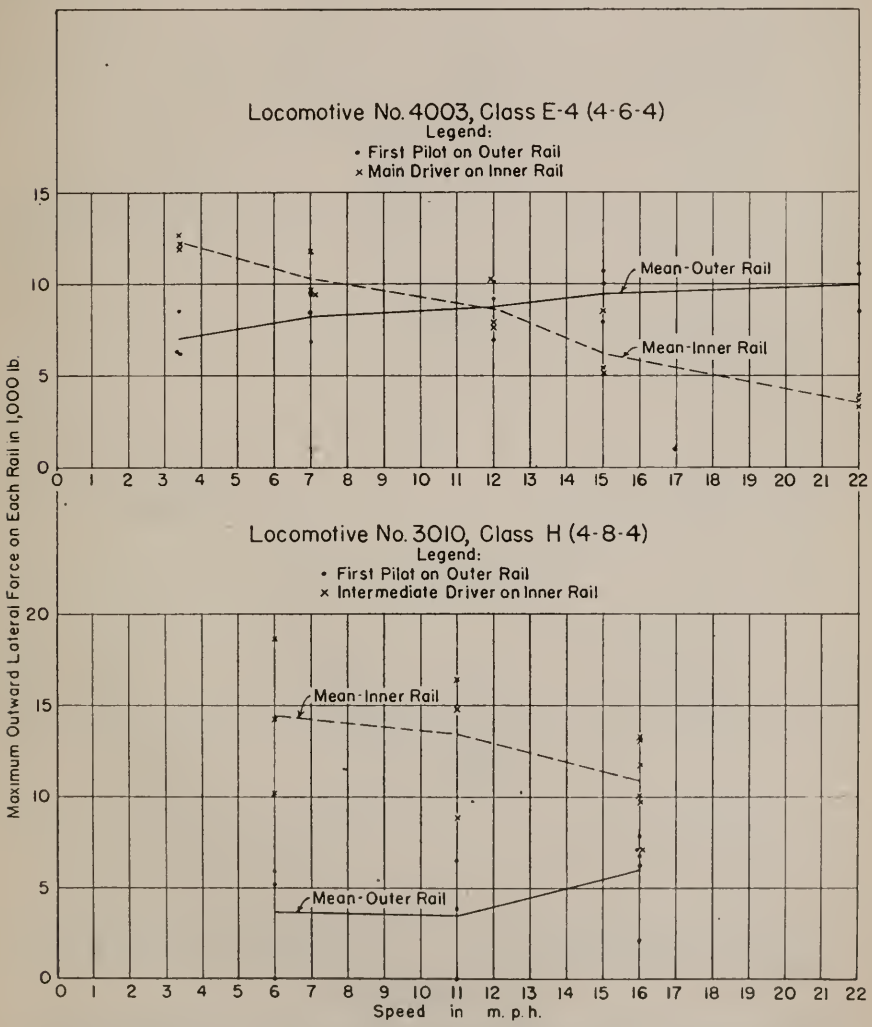

Fig. 10.—Maximum Outward Lateral Forces Exerted on the Inner and Outer Rails of Turnout No. 59 by Special 4–6–4 and 4–8–4 Type Locomotives when Making Facing Point or Westbound Movements.

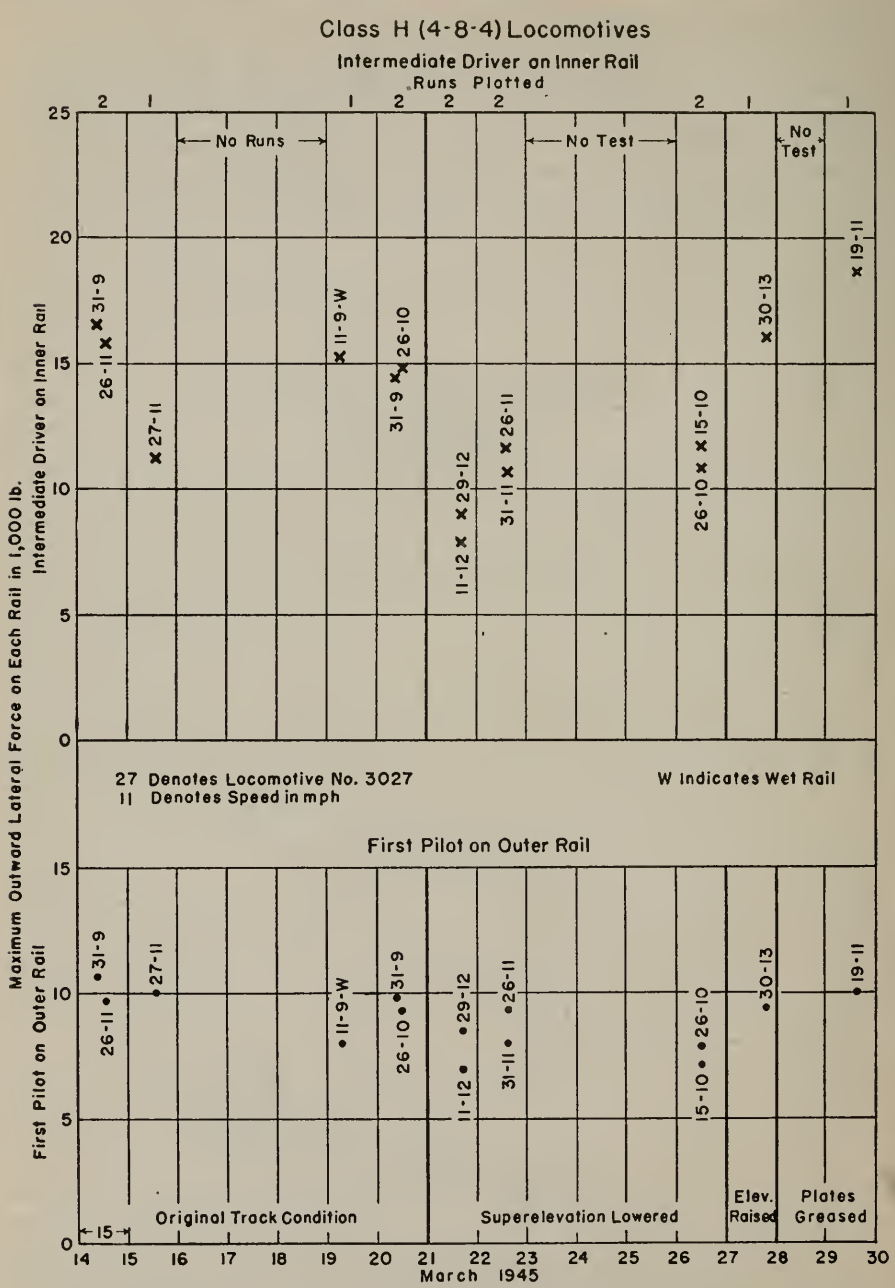

Fig. 11.—Daily Variation of Maximum Outward Lateral Forces Exerted on the Inner and Outer Rails of Turnout No. 59 by Several 4-8-4 Type Locomotives when Making Facing Point or Westbound Movements.

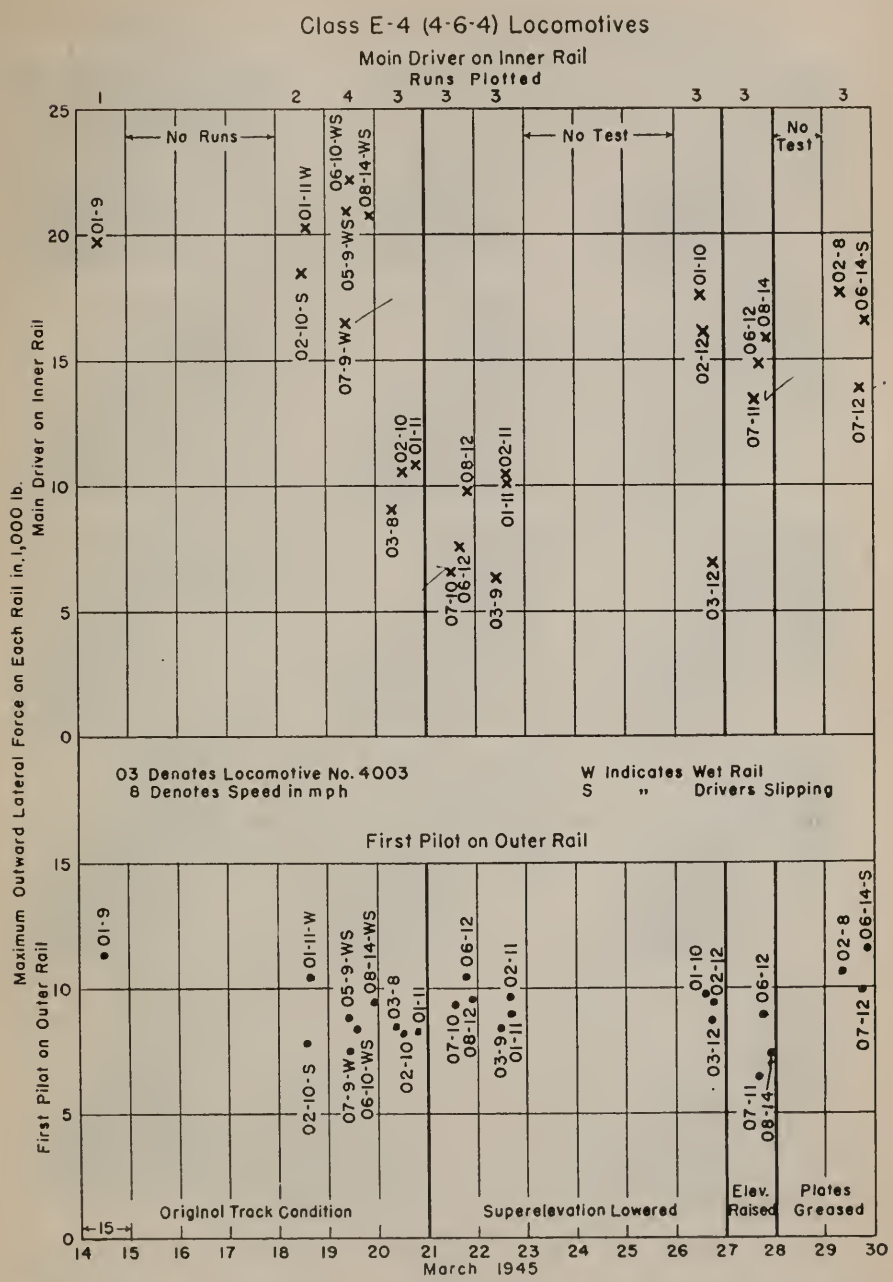

Fig. 12.—Daily Variation of Maximum Outward Lateral Forces Exerted on the Inner and Outer Rails of Turnout No. 59 by Several 4–6–4 Type Locomotives when Making Facing Point or Westbound Movements.

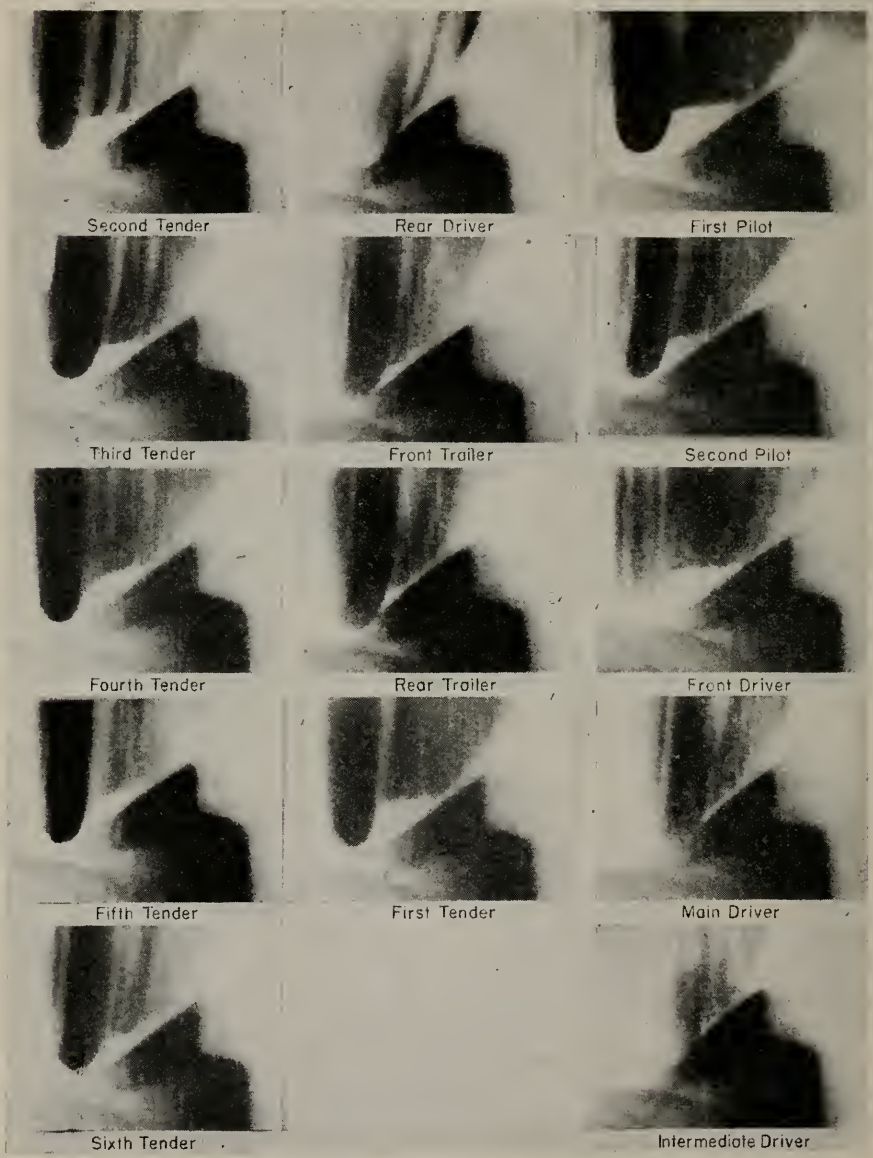

Fig. 13.—Flange Position of Left Wheels of Locomotive No. 3029, Class H (4–8–4) near Weigh Bar No. 5 on the Inner Rail of Turnout No. 59 when Moving Westbound with 15 Passenger Cars at a Speed of 12 mph. (Gage, 57 in., Elevation, ¾ in.).

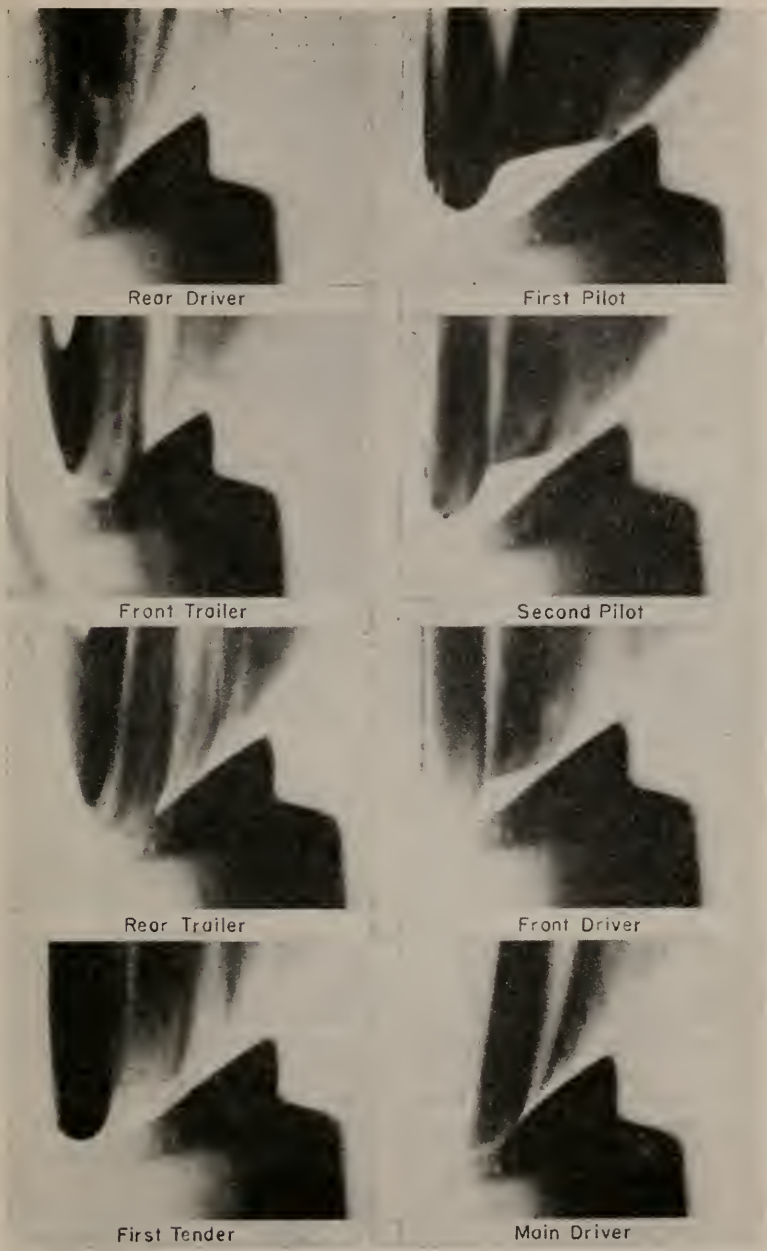

Fig. 14.—Flange Position of Left Wheels of Locomotive No. 4006, Class E–4 (4–6–4) near Weigh Bar No. 5 on the Inner Rail of Turnout No. 59 when Moving Westbound with 14 Passenger Cars at a Speed of 12 mph. (Gage, 57 in., Elevation, ¾ in.).

(4–8–4) and in Fig. 14 for locomotive 4006 (4–6–4) when making westbound movements and hauling regular passenger trains. In Fig. 13 the flange of the left intermediate driver was in contact with the inner rail head and the flanges of the left main and rear drivers were very close to the rail. The second pilot and both trailer wheels were fairly close to the inner rail and it is evident that the flanges of the right wheels on these axles were not in contact with the outer rail. The left front driver flange was in a position inward from the rail about the same amount as the left front pilot wheel.

It is therefore reasonable to assume that the right front driver flange may have been in contact with the outer rail. (When engine 3010 was stopped on the curve neither of the front driver flanges was in contact with the rail) All of the left tender wheel flanges were away from the inner rail and the right wheel flanges are probably not in contact with the outer rail as none of the forces was in excess of 4000 lb. In this run by engine 3029 the thrusts on the rail were very moderate. The mean maximum thrust on the outer rail by the first pilot was 8500 lb. and for the inner rail under the intermediate driver the corresponding value was 8900 lb.

The flange position pictures in Fig. 14 are for engine 4006 (4–6–4) in a westbound movement when hauling 14 cars at 12 mph. The left main driver flange was probably contacting the inner rail and the left rear driver and left front trailer flanges were close to the inner rail. The left first pilot flange has the most inward position and the companion flange is in contact with the outer rail. Both of the left trailer wheel flange positions are such that the right trailer flanges were not contacting the outer rail. From the position of the left first tender wheel it is assumed that the opposite flange is not contacting the outer rail. Furthermore, none of the forces exerted by any of the right tender wheels was in excess of 4000 lb. In this run the mean maximum thrust on the outer rail from the first pilot was 10,400 lb. and the corresponding value for the main driver on the inner rail was 7600 lb. As previously mentioned engine 4006 was classed as being moderately stiff.

Analytical Discussion of the Effect of Drawbar Pull on the Lateral Forces

Some of the thrusts measured on the inner rail were so high as to warrant an analysis of the effect of the lateral component of the drawbar pull acting through the angularity of the drawbar. For the 4–6–4 locomotives it is known that flange contact occurs against the outer rail under the first pilot wheel and on the inner rail under the main driver. It is logical to assume that there is no further lateral play between the frame and the two wheels in flange contact. Then the moment of the lateral component of drawbar pull about the center of rotation at the left main driver would be resisted by forces from the rail at these two points. Assuming the drawbar pull would amount to 45,000 lb. the additional force on the inner rail at the main driver would be 5500 lb. and on the front truck center pin would be 3500 lb. Obviously, some of the irregularity of the thrusts on the rails can be attributed to the variation in drawbar pull.

Effect of Radial Type Buffer Binding

It is common knowledge that when the buffer chafing surfaces have no lubrication, or have flat spots worn in the periphery, there is a binding action between the engine and tender which creates a lateral force probably greatly in excess of the drawbar pull lateral component. This condition will materially affect the lateral forces exerted on the test track.

Summary

1. The maximum lateral outward forces on one tie plate of the inner rail produced by the 4–8–4 and 4–6–4 locomotives were 24,200 and 26,800 lb., respectively. These forces are considerably in excess of the ultimate strength of a 5/8-in. square cut spike in single shear which is 16,100 lb. and 20,500 lb. for soft and high carbon steel, respectively.

2. The patterns of the lateral thrusts on the rails by the two classes of locomotives were very uniform but there was a large variation in the magnitude of these forces for individual locomotives and, in fact, for the same locomotive in successive runs.

3. The forces exerted on the rails by the trailers of both classes of power were of moderate magnitude.

4. Generally, in forward movements, the guiding thrust on the outer rail by the first pilot wheel was considerably smaller than the maximum force on the inner rail. These guiding forces are of reasonable magnitudes, with a few exceptions.

5. The effect of varying the track elevation upon the lateral forces measured by the weigh bars cannot be determined owing to the greater influence of other factors pertaining to the locomotives.

6. From Fig. 10 covering the tests of the two light locomotives at several speeds it is conclusive that the influence of speed on the magnitude of the thrusts against the rail is appreciable.

7. There was only a slight indication of an increase of the forces on the weigh bars when the tie plates and rail base were greased to minimize the lateral force transmitted by friction by the rail base to the tie plate.

From the results of these tests, the mechanical department of the North Western decided to modify one of the class H locomotives (4–8–4) by removing the lateral motion device from the front drivers and providing a pedestal play of 1/2 in. and reducing the engine truck resistance from 30 to 20 percent. Accordingly, these modifications were made to locomotive 3017 and the testing of this engine is described below.

Supplemental Tests of July 1945

Test Locomotive

In making class 5 repairs to locomotive 3017, class H (4–8–4) the Chicago & North Western Railway equipped all axles with roller bearings, removed the lateral motion device from the front drivers and provided 1/2-in. free lateral clearance instead of the 2 in. afforded by the lateral motion, and reduced the engine truck resistance from 30 to 20 percent. Mechanical lubrication for lubricating the chafing plates of the Franklin type E–2 radial buffer was also applied to this locomotive. Locomotive 3017 left the shop June 21, 1945 and was tested on July 5, 9 and 11. The total lateral play (box to frame) provided in the other axles follows: Front truck, 3/8 in.; main, intermediate and rear drivers, 3/8 in.; front trailer, 2 in. and rear trailer, 3/8 in.

Test Procedure

The weigh bars were reinstalled in the same locations as shown in Fig. 1 and records of stresses were taken of regular train movements over the turnout as well as a few runs of locomotive 3017, running light and headed west. The track had the same elevation, approximately 1 1/2 in., as at the close of the first test. No lubrication was used between the rail base and the tie plates.

Lateral Force Diagrams for Locomotive 3017 (4–8–4)

Three force diagrams for locomotive 3017 hauling approximately 15 passenger cars are shown in Fig. 15, the upper two being for westbound forward movements and the lower one for an eastbound back up movement. These diagrams were prepared similarly to those included in Figs. 8-a and 8-b and 9-a and 9-b and the forces are given in units of 1000 lb.

Run 10 was selected to show the largest force exerted on the inner rail by locomotive 3017 while run 16 shows a lower value. The diagram for run 13 includes the largest force exerted on the inner rail by the main drivers when backing up. In comparing these force diagrams with those of other class H locomotives in Figs. 8-a and 8-b it is noted that the larger forces imposed on the inner rail cover about the same range. In the westbound forward movements locomotive 3017 produced moderately lower forces on the outer rail by the first pilot. Further, there is a definite tendency for the front drivers of locomotive 3017, to provide more assistance to the front truck in guiding the

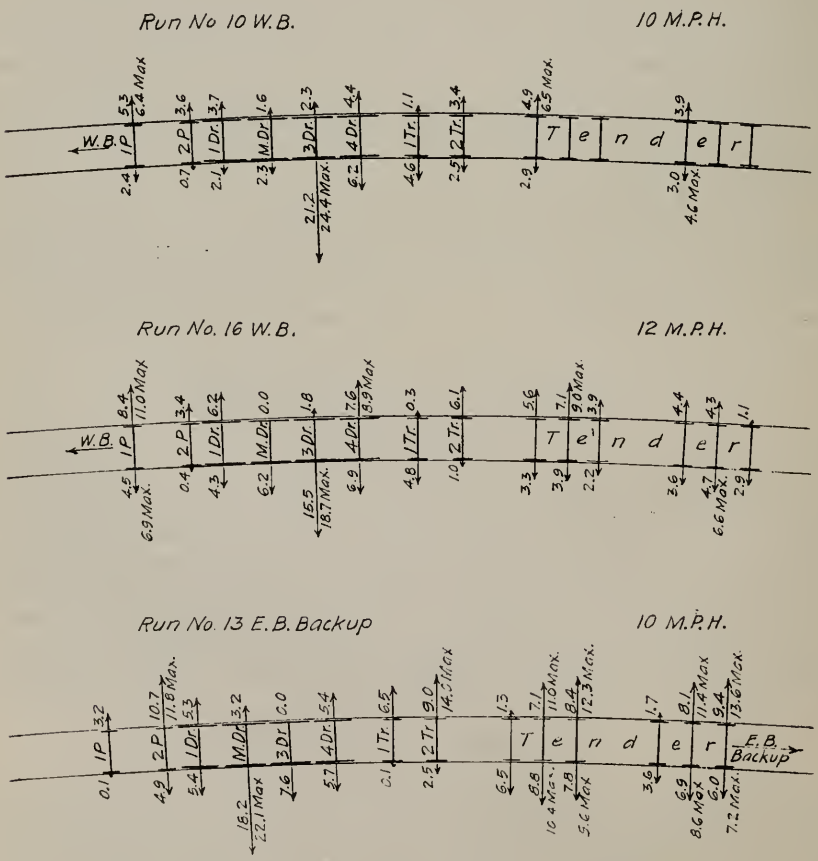

Fig. 15.—Lateral Force on Base of Rail in Thousands of Pounds, Locomotive 3017 (4–8–4).

locomotive than was true for the other class H engines. Also, in these movements, generally, a large force is transmitted from the intermediate drivers to the inner rail, while the lateral force on the same rail from the main drivers is less than one-half of the former in the case of locomotive 3017. However, in the first series of tests made in March 1945 the original H class locomotives likewise exerted a large force on the inner rail by the intermediate drivers, but usually the force from the main drivers was well above one-half the former thrust.

Effect of Speed on the Lateral Forces Against the Rails by Locomotive 3017

In Fig. 16 curves are shown for the mean maximum thrusts on the rails for locomotive 3017 when running light and making forward westbound movements. This figure is similar to the lower portion of Fig. 10 for locomotive 3010 (with friction driving boxes) and by comparison it is observed that locomotive 3017 exerted lower thrusts on the inner rail and slightly higher ones on the outer rail. Locomotive 3017 was just out of the shop while locomotive 3010 was in very loose condition.

Lateral Force Diagrams on the Through Rails of the Turnout

To obtain information on the extent to which the lateral forces were affected by the degree of curvature, the weigh bars were removed from the turnout rails and placed under the rails of the through track having a curvature of 7 deg. 30 min. Each weigh bar was placed on the same switch tie. Oscillograph records were taken of the regular movements with approximately 15 passenger cars for one evening and typical lateral

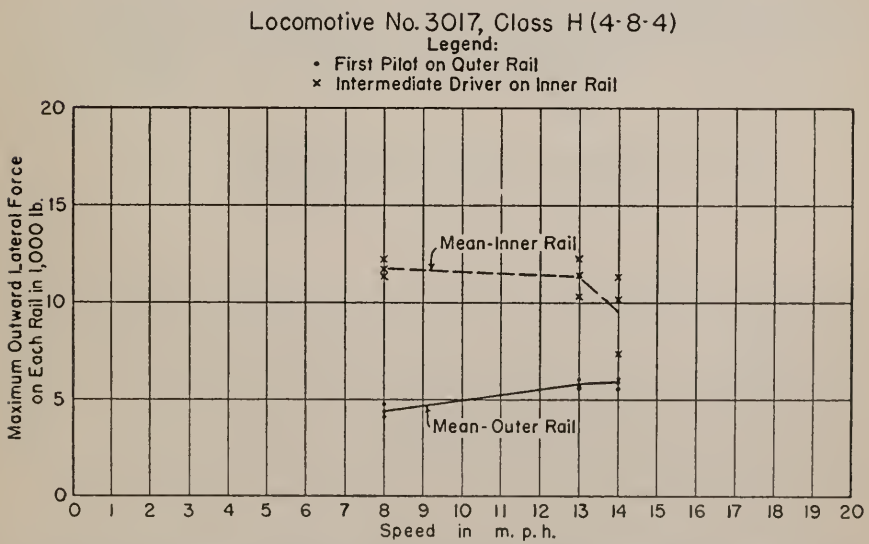

Fig. 16.—Maximum Outward Lateral Forces Exerted on the Inner and Outer Rails of Turnout No. 59 by Special 4–8–4 Type Locomotive when Running Light and Making Facing Point or Westbound Movements.

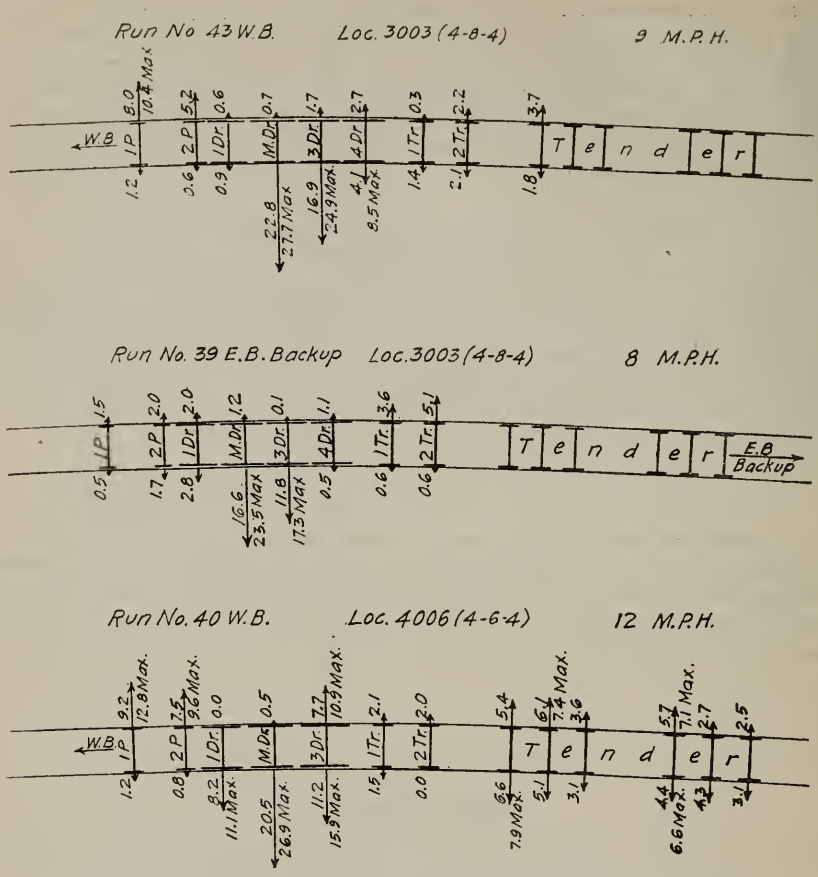

Fig. 17.—Lateral Force on Base of Rail in Through Side of Turnout in Thousands of Pounds, 7-Deg. 30-Min. Curve.

force diagrams of classes H (4–8–4) and E-4 (4–6–4) locomotives are shown in Fig. 17. Locomotive 3017 did not operate over this track while the test was made and, therefore, diagrams for locomotives 3003 (4–8–4) were prepared for the class H locomotives. By comparing the forces developed in runs 43 and 39 (Fig. 17) for locomotive 3003 (4–8–4) with the corresponding diagrams of other class H locomotives (Figs. 8-a and 8-b and 15) it will be noted the magnitudes of the maximum forces on each rail of 7-deg. 30-min. curve are quite close to those obtained on the turnout rails having 10-deg. 30-min. curvature. Locomotive 3003 with roller bearings on all journals had been last shopped (class 2 repairs) in July 1944 and would not be considered as being stiff.

The diagram for locomotive 4006 (4–6–4) run 40, Fig. 17, shows large forces on the inner rail under the main drivers and their magnitude is approximately equal to those forces measured under other locomotives of the same class for the inner rail of the 10-deg. 30-min. curve.

Because a comparatively small number of test runs were made with locomotive 3017 (4–8–4) when hauling cars, and also since only one locomotive was so modified, an exact appraisal of the merits of the modified locomotive can not be made. However, the following comparisons with the original class H locomotives seem justified.

1. In the forward westbound movements, when hauling cars, the maximum guiding thrusts under the first pilot of locomotive 3017 (4–8–4) were moderately lower than the corresponding values with the original class H locomotives. Also, with locomotive 3017 there was a noticeable tendency for the front driver to assist the front truck more in turning the locomotive on the test curve.

2. Generally, in the forward westbound movements the original class H locomotives produced two large thrusts against the inner rail, one at the intermediate driver and the other at the main driver, the latter being approximately 70 percent of the former. In the test runs made with locomotive 3017, only the intermediate driver produced a large thrust on the inner rail, the lateral force under the main wheel being reduced to approximately 30 percent of that at the intermediate driver. The amount of the maximum force on the inner rail applied by the intermediate driver of locomotive 3017 was not appreciably reduced from the corresponding values measured in the first series of tests for other locomotives of this same class (see Figs. 15 and 11).

3.The observed thrusts applied by each class of power on the 10-deg. 30-min. and 7-deg. 30-min. curves were not appreciably different. It is evident that the variability in the conditions and operation of different locomotives of the same class of power has a greater effect on the forces exerted on the track than the change in track from a 10-deg. 30-min. to a 7-deg. 30-min. curve on both of which the gage is ¼ in. wide between the switch and the frog.

Future Tests

The results from these tests emphasize the need for conducting tests of considerable scope and refinement to determine the proper truck resistance required for the various types of trucks and locomotives so as to provide the desired stability to the locomotive with minimum damage to the track.

Two Problems in Bridge Design

By L. T. Wyly

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Summary

General solutions are presented for the analysis of rigid frame action due to floorbeam deflection and to lateral loads on portals, and typical examples are investigated. The conclusion is reached that such stresses are frequently fairly high, and the recommendation is made that the design specifications should provide for the computation of such stresses and for the proportioning of the material for them in a rational manner.

Introduction

There are presented here general solutions of two problems in bridge design which frequently receive inadequate treatment:

1. Bending and shearing stresses in posts due to floorbeam deflection.
2. Bending and shearing stresses due to lateral loads on unbraced portal posts of through bridges.

Modern railway bridge specifications require that bending in the verticals due to floorbeam deflection be taken into account, but the shearing stresses set up in the lacing and the lacing connections are commonly neglected. Both bending and shearing stresses are frequently overlooked altogether in highway bridge specifications. Portal bending stresses are computed as a general practice but specifications for both railway and highway bridges are usually silent about the shears induced by the lateral loads, although these shears are frequently quite large.*

Two types of frame are considered here:

1. Frames having sway or lateral bracing, i.e. deck bridges of any span and through bridges of longer span.
2. Frames of through bridges having top struts and brackets without other transverse bracing.

The solutions presented here comprise:

Ordinary Method

1. Graphs showing coefficients of bending moments for use in preliminary designs and suitable for the most common cases where members have a constant cross section throughout their length.
2. Formulas for distortions and stresses for use in final designs where more than ordinary accuracy is desired. These formulas include stresses in the bracing also.
3. General solutions for the above graphs and formulas.

* Paragraph 420 of the AREA Specifications for Steel Railway Bridges for 1943 specifies that to the shear allowed for ordinary secondary bending and for the assumed initial eccentricities and curvature, there is to be added "any shear due to the weight of the member or to other forces." However, at the present time it is not customary to include the shears due to rigid frame action in the above category.

Bulletin 454, September–October 1945.

Modified Method (Taking into account the width of the members)

1. Formulas for distortions and stresses where the width of the members entering the joint is taken into account in a rational manner.
2. General solutions for the above formulas.

Members with Variable Cross Sections

Curves and formulas for the moment coefficients are given for members whose cross section (moment of inertia) is changed at some point by the addition of cover plates or reinforcing material over part of the length. See Fig. 3.†

Notations and Conventions Not Covered in Text

k. denotes a kip or 1000 lb.

ksi. denotes kips per sq. in.

ft.k. denotes feet-kip

Throughout this paper bending moments are plotted on the tension side of the member.

The solutions presented here will enable the designer to compute both bending moments and shears very quickly for all common cases. The graphs should be accurate enough for preliminary designs and in many cases for final designs and the formulas can be used where more refinement is desired. So far as the writer knows this material has not been published before.

Examples

For all cases typical examples are given in detail, with all computations. The requirements for a structure to be so investigated are:

(a) It should represent good modern design.

(b) Complete design details are required and such details should be readily accessible to all interested readers.

Accordingly the bridges listed in Fig. 1 were selected.

Assumptions

It is generally recognized that it is neither feasible nor desirable to determine accurately all stresses in all parts of a structure for a given loading. What is desirable is a fairly reliable computation of the significant stresses. Accordingly certain simplifying assumptions are made which facilitate the analysis without seriously affecting the values of the significant stresses. It is always necessary that the limitations of the method be understood and that all assumptions be clearly stated. The principal assumptions made in this paper concern span length and joint fixity, and in all cases these assumptions are shown on the diagrams.

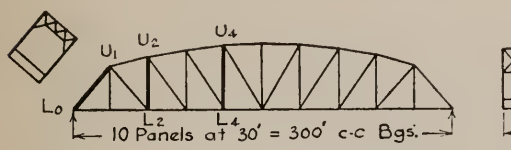
Method of Analysis

Where the width of one or all members entering a joint is considerable, it is common practice to assume the clear span in computing distortions and distortion stresses, since relatively little deformation occurs inside a well constructed structural joint. This practice has been followed in this paper. The slope deflection method[1] has been used and this treatment designated as the "Standard Method." See Fig. 2.

[1] Statically Indeterminate Stresses, Parcel and Maney, 2nd Ed. p. 147 ff.

† The curves and formulas shown here were computed by the writer for this paper. Similar curves are given in: Rigid Frames by L. T. Evans, p. 227ff for the members of Fig. 1(a). The values shown by Mr. Evans must be divided by two to use with the formulas of this paper.

Certain errors frequently arise from the above assumptions of span length. Thus in Fig. 6 it is plain that the vertical is not only twisted through the angle θ_A at the top of the floorbeam but there is also a horizontal displacement Δ_{AB} of the vertical at the same point. The stresses due to the rotation are obtained by the standard method but those due to horizontal displacement are not so obtained. Also, the use of clear spans assumes that the algebraic sum of moments at the faces of the joint is zero, whereas it is the sum of the moments at the joint center which must add up to zero. If the standard slope-deflection method be modified by placing the summation of moments about the joint center J_A equal to zero (Fig. 6) and by including the effect of shifting of the ends of the members, normal to their axes, at the faces of the support, then a rational procedure is obtained which is probably about as accurate as one can hope to get. Such a

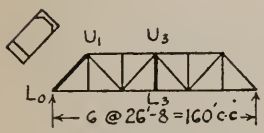


Reference,

For details of this bridge see "Structural Design in Steel" by, T.C.Shedd, pp. 461-480 incl. and Plates VII,VIII, and IX.

Page references in examples are to above text.

(a) 300 Ft. Span Railway Bridge. E60 Loading Double Track.



Reference;

For details of this bridge see "Steel and Timber Structures", by Hool and Kinne, pp. 328-341 incl. and Fig. 44.

Page references in examples are to above text.

(b) 160 Ft. Span Railway Bridge. E60 Loading Single Track.

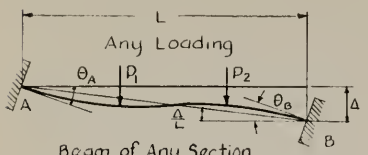
Fig. 1.—Structures Used as Examples.

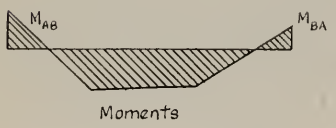
procedure was developed by the writer some time ago in investigating the secondary stresses in trunnion column frames and in the rear end of bascule trusses where the gussets are very large compared to the length of the members connected. Later the writer published an analysis of rigid frame concrete members by this method.[2] This treatment has been included here for the frames under study and designated the "Modified Method." Admittedly, this procedure is very tedious and hardly applicable to common use for that reason. However, in the writer's opinion, it is very useful in checking the results of a general solution by the standard method and is included for that purpose.

Using the sign convention shown in Fig. 2 it is evident that a positive value of Δ/L will produce positive end moments in a member, while a positive value of θ will produce negative end moments in the same member, hence the formula shows these effects to have opposite signs. In procedure the value of the θ is usually assumed positive in writing the joint equations, and the sign when found must then be used in writing the final end moments. Thus in example No. 2, Fig. 20, θ_B is found to be negative, and this sign is then used in computing the end moments where θ_B occurs. If care is taken in this matter of signs no trouble should be encountered with the method.

[2] Discussion by L. T. Wyly of "Analysis of Multiple Span Rigid Frame Bridges by the Slope Deflection Method," Journal of the American Concrete Institute, Sept.–Oct. 1936, pp. 767–770.

(text continued on page 706)





Fundamental Equations

General Form, Beam of Any Cross Section

$$\left.\begin{aligned} M_{AB} &= \pm M_{FAB} + 2E\frac{I}{L}\left[(C_{AB}+C'_{AB})\frac{\Delta}{L} - C_{AB}\theta_A - C'_{AB}\theta_B\right] \\ M_{BA} &= M_{FBA} + 2E\frac{I}{L}\left[(C_{BA}+C'_{AB})\frac{\Delta}{L} - C_{BA}\theta_B - C'_{AB}\theta_A\right] \end{aligned}\right\} \quad (1)$$

Usual Form, Beam of Constant Cross Section

$$M_{AB} = \pm M_{FAB} + 2E\frac{I}{L}\left(3\frac{\Delta}{L} - 2\theta_A - \theta_B\right) \quad (2)$$

Reference Statically Indeterminate Stresses, Parcel and Maney, 2nd Ed. pp. 147-166

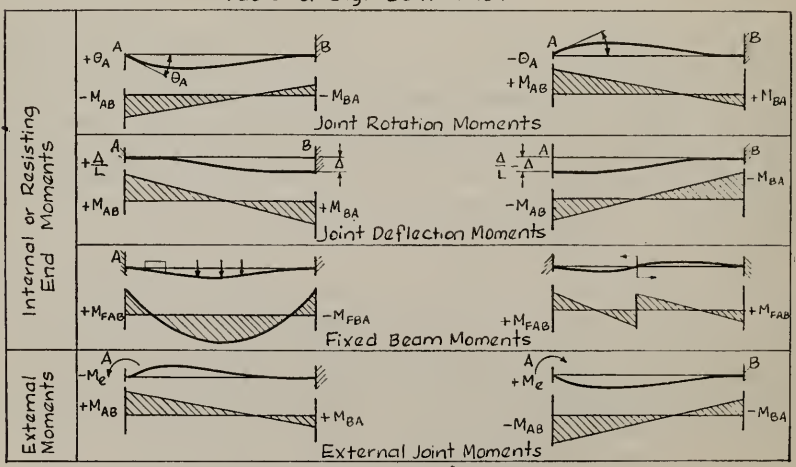
Notation

- M_{AB} = Final end moment at A in any member AB
- M_{FAB} = Fixed beam end moment at A in member AB when $\theta_A = \theta_B = 0$ and $\frac{\Delta}{L} = 0$
- $\frac{EI}{L}$ = Product of modulus of elasticity and moment of inertia of member divided by its length, the length taken in inches.
- θ_A = Joint rotation at A in radians
- Δ = Displacement in direction normal to axis of member of one end relative to the other, in inches.
- C_{AB} = Coefficient of moment at A due to joint rotation θ_A
- C'_{AB} = Coefficient of moment at A or B due to joint rotation θ_B or θ_A respectively
- C_{BA} = Coefficient of moment at B due to joint rotation θ_B

Sign Conventions

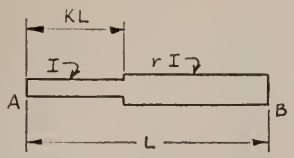
Angles θ and $\frac{\Delta}{L}$ are positive when generated in clockwise direction
End moments in members are positive when the moment tends to rotate the joint (not the member) in clockwise direction

Table of Sign Conventions

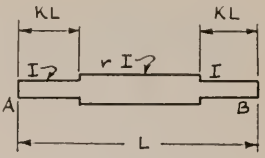


Note: Moments plotted on tension side of beam

Fig. 2.—Fundamental Slope Deflection Equations.



(a)



(b)

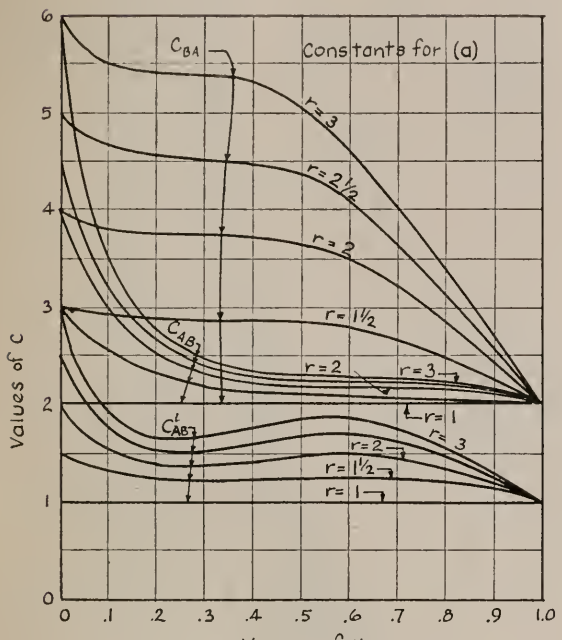


Fig. 1 (a)

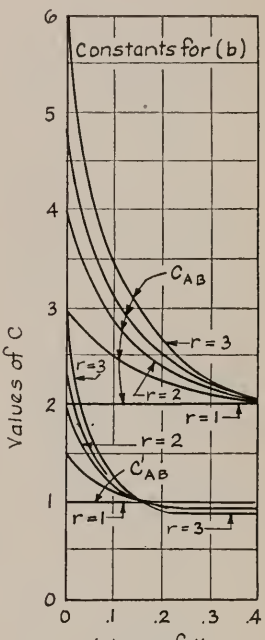


Fig. 1 (b)

Equations for Values of Constants

Fig. 1 (a)

$$C_{AB} = 2r\frac{1+k^3(r-1)}{D}$$

$$C'_{AB} = r\frac{1+k^2(3-2k)(r-1)}{D}$$

$$C_{BA} = 2r\frac{1+k(3-3k+k^2)(r-1)}{D}$$

Where $D = 1+k[2(2-3k+2k^2)+k^3(r-1)](r-1)$

Fig. 1 (b)

$$C_{AB} = 2r\frac{1+k(3-3k+2k^2)(r-1)}{D}$$

$$C'_{AB} = r\frac{1+2k^2(3-2k)(r-1)}{D}$$

Where $D = 1+8k(r-1)-12k^2(3r-2)+8k^3(7r-4)-16k^4(2r-1)+4k^2(3-6k+4k^2)r^2$

Fig. 3.—Slope Deflection Constants for Members with Reinforced Sections.

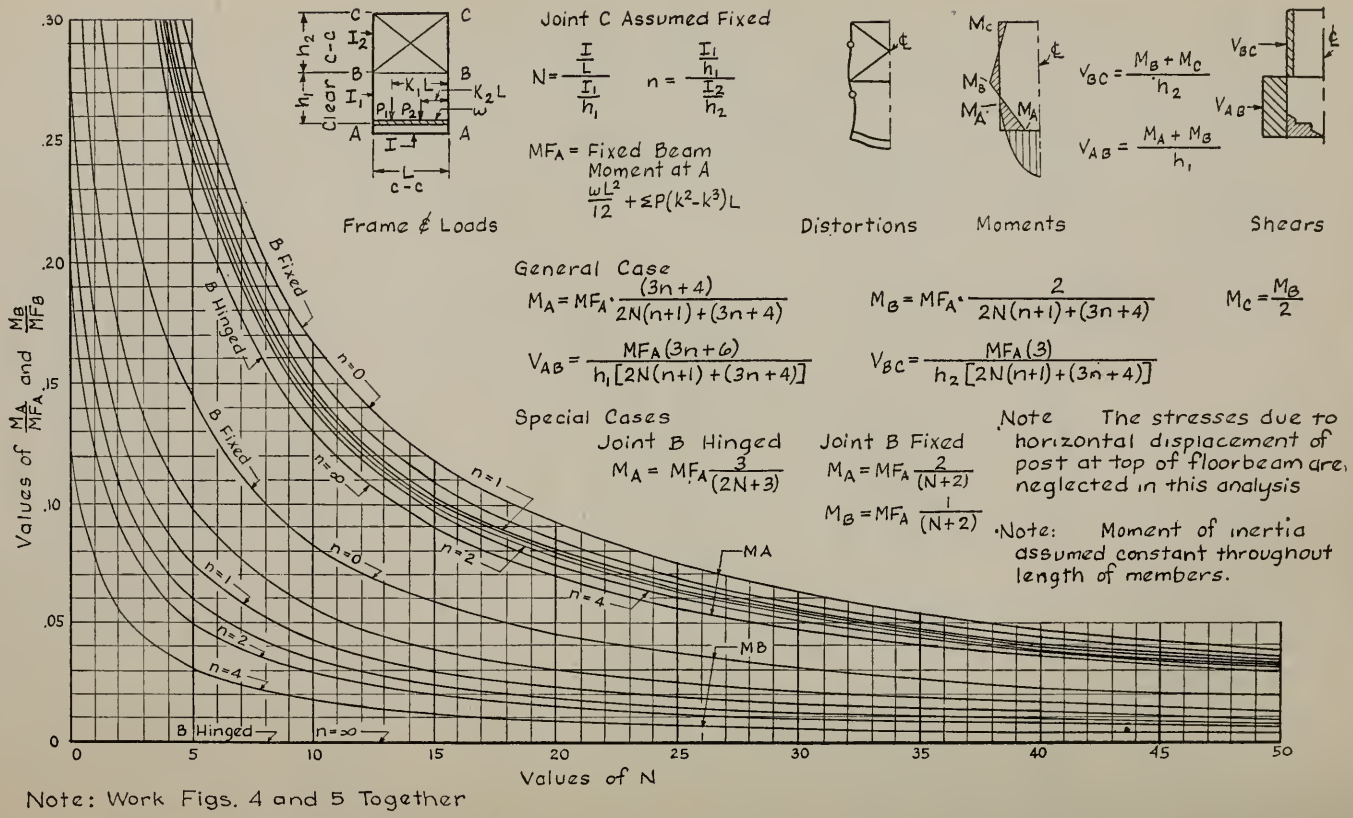


Fig. 4.—Floorbeam Deflection Stresses. Frame with Sway Bracing, Standard Method.

Procedure

The algebraic sum of the end moments for all members entering a joint must be zero The end moments, in terms of the joint rotation angles θ, are given by the fundamental slope deflection Equations (2) shown in Fig. 1. An equilibrium equation for the joint is obtained by placing the summation of the end moments equal to zero, the unknowns being the joint rotation angles θ. The values of the angles θ are obtained by the simultaneous solution of the joint equations. The values of the end moments are then obtained when the values of the angles θ are inserted in the original elastic end moment equations.

Equilibrium equations at Joints

Joint A $M_{AA} = M_{FAA} + 2EN\frac{I_1}{h_1}[-\theta_A]$

$M_{AB} = 2E\frac{I_1}{h_1}[-2\theta_A-\theta_B]$ } Equations (2) Fig. 1.

$$0 = \frac{M_{FAA}}{2E\frac{I_1}{h_1}} - \theta_A[N+2] - \theta_B \qquad \text{(A)}.$$

Joint B $M_{BC} = 2E\frac{I_1}{nh_1}[-2\theta_B]$

$M_{BA} = 2E\frac{I_1}{h_1}[-2\theta_B-\theta_A]$ } Equations (2) Fig. 1.

$$0 = -\theta_B\frac{2(n+1)}{n} - \theta_A \qquad \text{(B)}.$$

Note: Work Figs. 4 and 5 together.

Solving Joint Equations (A) and (B) Simultaneously:

$$\theta_A = \frac{M_{FAA}}{2E\frac{I_1}{h_1}} \cdot \frac{2(n+1)}{[2N(n+1)+(3n+4)]} \qquad \theta_B = -\frac{M_{FAA}}{2E\frac{I_1}{h_1}} \cdot \frac{n}{[2N(n+1)+(3n+4)]}$$

End Moments

The end moments, obtained by inserting the above values of θ in the original Equations (2) above, are shown in Fig. 3.

Shears

The shears in the verticals are obtained by dividing the algebraic difference of the end moments of a member by its length, (See Fig. 3.) considering sign of moment.

Stresses in the Sway Bracing

The loading diagram for the vertical with floorbeam and bracing removed is shown in (a) The reactions at Points B and C are taken by the bracing, i e the horizontal members, since the diagonals usually would be too slender to take compression. The top strut should take the moments M_c if it is stiff enough to do so.

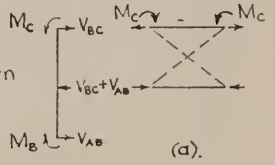


Fig. 5.—General Solution of Frame of Fig. 4.

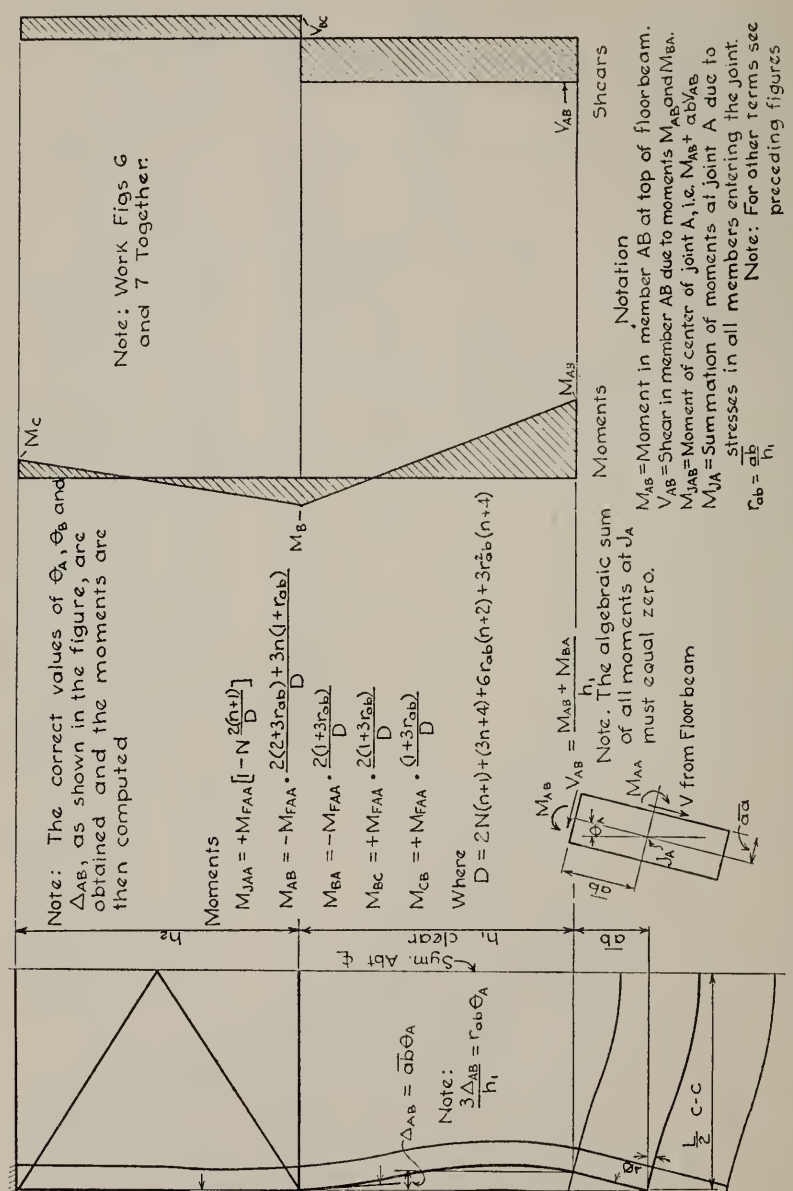


Fig. 6.—Floorbeam Deflection Stresses. Frame with Sway Bracing, Modified Method.

Procedure

Expressions for the moments M_{AB} (at top of floorbeam) and M_{BA} are written in terms of the θ and Δ values and the expression for the shear V_{AB} is obtained. The equilibrium equations for the joints are then written and the procedure of Fig. 5 is carried out.

Expression for V_{AB}

$$M_{AB} = 2E\frac{I_1}{h_1}[-3r_{ab}\theta_A - 2\theta_A - \theta_B]$$

$$M_{BA} = 2E\frac{I_1}{h_1}[-3r_{ab}\theta_A - \theta_A - 2\theta_B]$$

$$V_{AB} = \frac{M_{AB}+M_{BA}}{h_1} = 2E\frac{I_1}{h_1}[-\theta_A(3+6r_{ab}) - 3\theta_B] \div h_1$$

$$\overline{ab}V_{AB} = 2E\frac{I_1}{h_1}[-\theta_A(3+6r_{ab}) - 3\theta_B]r_{ab}$$

Note: These are Equations (2) of Fig. 2.

Equilibrium Equations at Joints

Joint A

$$M_{JAA} = M_{FAA} + 2EN\frac{I_1}{h_1}[-\theta_A]$$

$$M_{AB} = 2E\frac{I_1}{h_1}[-\theta_A(2+3r_{ab}) - \theta_B]$$

$$\overline{ab}V_{AB} = 2E\frac{I_1}{h_1}[-\theta_A(3+6r_{ab}) - 3\theta_B]r_{ab}$$

$$0 = \frac{M_{FAA}}{2E\frac{I_1}{h_1}} - \theta_A[N+2+6r_{ab}+6r_{ab}^2] - \theta_B[1+3r_{ab}] \quad (A)$$

Joint B

$$M_{BC} = 2E\frac{I_1}{nh_1}[-2\theta_B]$$

$$M_{BA} = 2E\frac{I_1}{h_1}[-\theta_A(1+3r_{ab}) - 2\theta_B]$$

$$0 = -\theta_A[1+3r_{ab}] - \theta_B\left[\frac{2(n+1)}{n}\right] \quad (B)$$

Solving Joint Equations (A) and (B) Simultaneously:

$$\theta_A = \frac{M_{FAA}}{2E\frac{I_1}{h_1}} \cdot \frac{2(n+1)}{D} \qquad \theta_B = -\frac{M_{FAA}}{2E\frac{I_1}{h_1}} \cdot \frac{n(1+3r_{ab})}{D}$$

$$\frac{3\Delta_{AB}}{h_1} = \frac{M_{FAA}}{2E\frac{I_1}{h_1}} \cdot \frac{6r_{ab}(n+1)}{D}$$

Where $D = 2N(n+1) + (3n+4) + 6r_{ab}(n+2) + 3r_{ab}^2(n+4)$

End Moments

The end moments at top of floorbeam and at B and C are obtained by inserting the above θ and Δ values in the original equations used at the joints and are shown in Fig. 6.

Note: Work Figs. 6 and 7 together.

Fig. 7.—General Solution of Frame of Fig. 6.

(text continued from page 699)

Floorbeam Deflection Stresses

Example No. 1.—Frame with Sway Bracing (Figs. 4, 5, 6, 7, 16, 17, 18)

The stresses in the posts at U_4–L_4 of the 300-ft. double track span listed in Fig. 1 (a) are analyzed. Complete structural details are given in Professor Shedd's text.[3]

The fixed beam end moment computation is shown in detail in Fig. 16. If it is desired to take into account the fact that the moment of inertia of the floorbeam is not constant, this can be done using the moment coefficients, taken from Fig. 3, in the slope deflection equations. It will be noted that for the beam under consideration the usual assumption of constant moment of inertia gives results that are within 4 percent of the correct value and are on the safe side. Accordingly the results of the simpler calculation have been used in the rest of the work.

Analysis of the frame by the standard method is shown in Fig. 17. The formulas have been used in the figure, but the moment coefficients could have been scaled off the graph in Fig. 4 with good accuracy. It will be noted in Fig. 4 that the end moment of the floorbeam and the end moment at the bottom of the vertical, depend almost entirely upon the ratio of the I/L of the floorbeam to that of the post, and that this moment is influenced relatively little by the degree of restraint at B. Similarly the degree of restraint at C has little effect on the moment at B. As the joint at C is probably much more nearly fixed than hinged, the fixed condition has been assumed here. The significant stresses are the moments at A and B and the shears in AB. Obviously the rotation of the end of the floorbeam is resisted not only by the vertical but by the stiffness in bending and torsion of the truss diagonal and bottom chord framing into L_4. A similar condition obtains at U_4. However, it is hardly feasible to take these participation stresses in the other truss members into account.

Summarizing the analysis by the standard method, the following points stand out:

1. The bending stress in the vertical is considerably in excess of that permitted in Par. 218 of the AREA Specifications for 1943,‡ although the width of the member is materially less than the allowable width by the same paragraph, in other words, it is plain that a minimum width-to-length specification will not guarantee minimum bending stresses.
2. The shear due to flexure in the frame is about 50 percent of that specified to take care of column action under the average eccentricities assumed by Par. 420 of the AREA specifications. This 50 percent additional shear will be found to have overstrained the lacing and lacing connection rivets by about 50 percent of the design load.

In this analysis the length of post AB has been measured from the top of the floorbeam, since the twisting of the post, due to rotation of the joint A, occurs there. However, the analysis neglects the horizontal displacement, Δ_{AB}, towards the center of the span, of the end of the post at the top of the floorbeam. An approximate correction may be made by adding the stresses due to this displacement to those previously found. This calculation shows a very considerable increase in the bending and shear in the vertical.

The analysis by the modified method (Fig. 18) shows a quite substantial increase over the results of the standard method, though less than would be obtained if the correction stresses were added to the standard method stresses.

[3] Structural Design in Steel by Thomas Clark Shedd.

‡ It should be noted that the 1944 AREA Specifications (Par. 216) require that total combined stress, axial and bending, in the vertical should not exceed the allowable unit stress.

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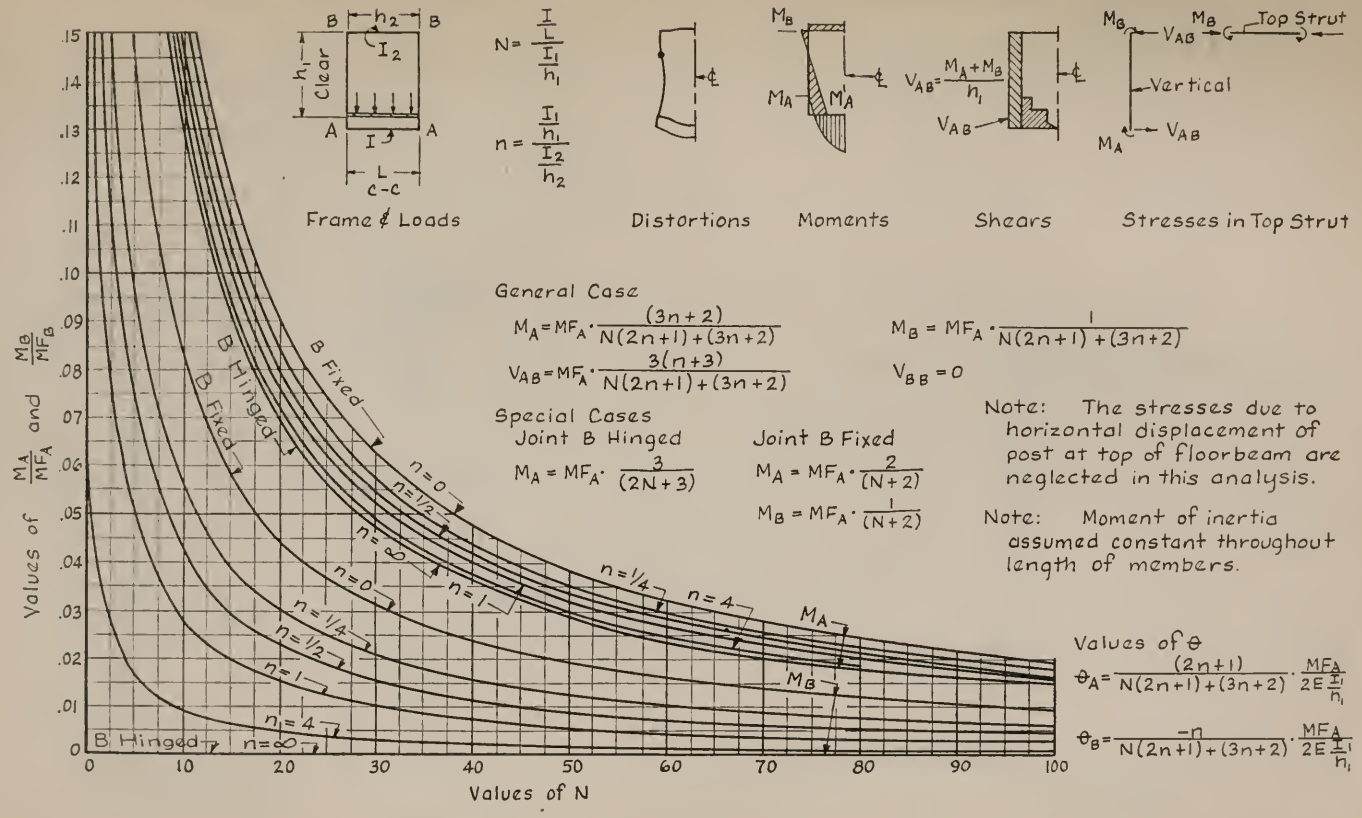
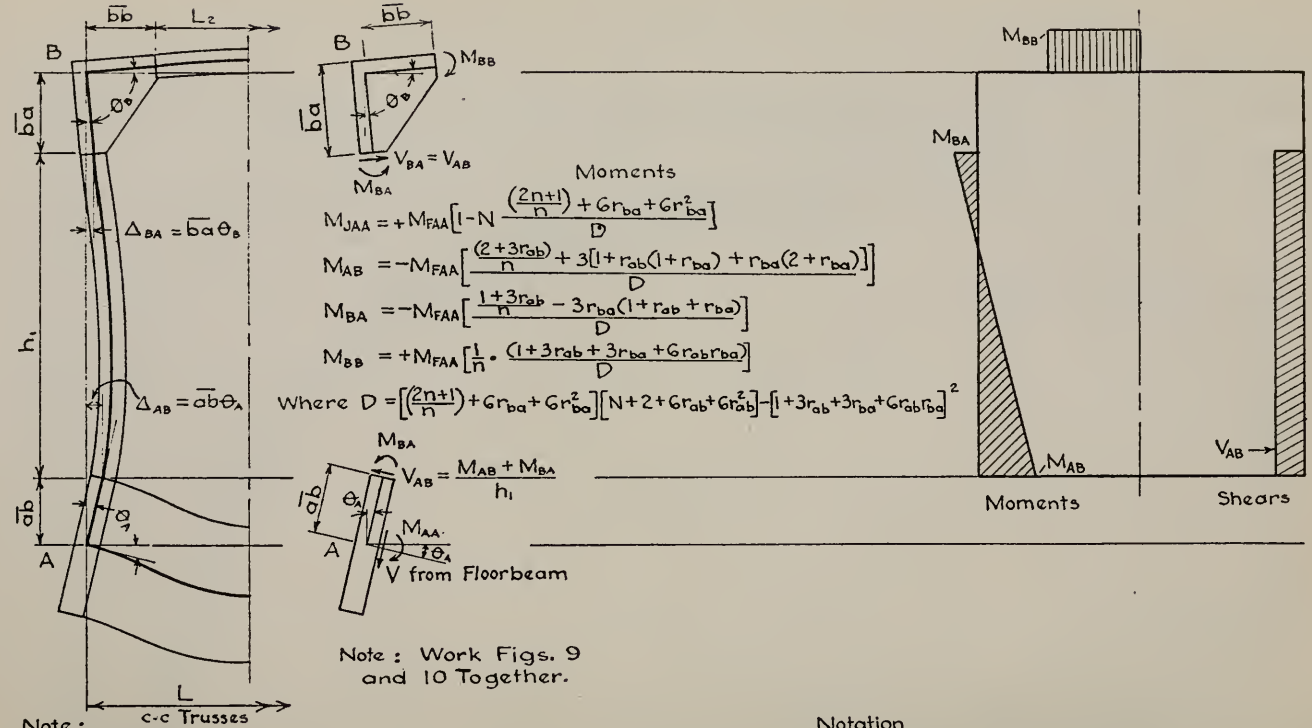


Fig. 8.—Floorbeam Deflection Stresses. Frame with Bracket, Standard Method.



Moments

$$M_{JAA} = +M_{FAA}\left[1 - N\,\frac{\left(\frac{2n+1}{n}\right) + Gr_{ba} + Gr_{ba}^2}{D}\right]$$

$$M_{AB} = -M_{FAA}\left[\frac{\frac{(2+3r_{ab})}{n} + 3\left[1 + r_{ab}(1+r_{ba}) + r_{ba}(2+r_{ba})\right]}{D}\right]$$

$$M_{BA} = -M_{FAA}\left[\frac{\frac{1+3r_{ab}}{n} - 3r_{ba}(1+r_{ab}+r_{ba})}{D}\right]$$

$$M_{BB} = +M_{FAA}\left[\frac{1}{n}\cdot\frac{(1+3r_{ab}+3r_{ba}+Gr_{ab}r_{ba})}{D}\right]$$

Where $D = \left[\left(\frac{2n+1}{n}\right) + Gr_{ba} + Gr_{ba}^2\right]\left[N + 2 + Gr_{ab} + Gr_{ab}^2\right] - \left[1 + 3r_{ab} + 3r_{ba} + Gr_{ab}r_{ba}\right]^2$

Note: Work Figs. 9 and 10 Together.

Note:

$$\frac{3\Delta}{h_1} = \frac{3(\Delta_{AB} - \Delta_{BA})}{h_1} = 3(r_{ab}\theta_A + r_{ba}\theta_B)$$

Notation

$r_{ba} = \frac{\overline{ba}}{h_1}$ $\qquad$ $r_{bb} = \frac{bb}{L_2}$

For other terms see preceding figures

Fig. 9.—Floorbeam Deflection Stresses. Frame with Top Strut and Brackets, Modified Method.

Procedure

Expressions for M_{AB} and M_{BA} (at top of floorbeam and bottom of bracket) are written in terms of the Θ and Δ values and the expression for the shear V_{AB} is obtained. The equilibrium equations for the joints are then written and the procedure of Fig. 5 is carried out.

Expression for V_{AB}

$$M_{AB} = 2E\frac{I_1}{h_1}[-3(r_{ab}\Theta_A + r_{ba}\Theta_B) - 2\Theta_A - \Theta_B]$$

$$M_{BA} = 2E\frac{I_1}{h_1}[-3(r_{ab}\Theta_A + r_{ba}\Theta_B) - \Theta_A - 2\Theta_B]$$

$$V_{AB} = \frac{M_{AB}+M_{BA}}{h_1} = 2E\frac{I_1}{h_1}[-\Theta_A(3+6r_{ab}) - \Theta_B(3+6r_{ba})] \div h_1$$

$$\overline{ab}V_{AB} = 2E\frac{I_1}{h_1}[-\Theta_A(3+6r_{ab}) - \Theta_B(3+6r_{ba})]r_{ab}$$

$$\overline{ba}V_{AB} = 2E\frac{I_1}{h_1}[-\Theta_A(3+6r_{ab}) - \Theta_B(3+6r_{ab})]r_{ba}$$

Note: These are Equations (2) of Fig 2.

Equilibrium Equations at Joints

Joint A

$$M_{JAA} = M_{FAA} + 2EN\frac{I_1}{h_1}(-\Theta_A)$$

$$M_{AB} = 2E\frac{I_1}{h_1}[-\Theta_A(2+3r_{ab}) - \Theta_B(1+3r_{ba})]$$

$$\overline{ab}V_{AB} = 2E\frac{I_1}{h_1}[-\Theta_A(3+6r_{ab}) - \Theta_B(3+6r_{ba})]r_{ab}$$

Joint B

$$M_{JBB} = 2E\frac{I_1}{nh_1}[-\Theta_B]$$

$$M_{JBA} = 2E\frac{I_1}{h_1}[-\Theta_A(1+3r_{ab}) - \Theta_B(2+3r_{ba})]$$

$$\overline{ba}V_{AB} = 2E\frac{I_1}{h_1}[-\Theta_A(3+6r_{ab}) - \Theta_B(3+6r_{ab})]r_{ba}$$

$$0 = \frac{M_{FAA}}{2E\frac{I_1}{h_1}} - \Theta_A[N+2+6r_{ab}+6r_{ab}^2] - \Theta_B[1+3r_{ab}+3r_{ba}+6r_{ab}r_{ba}] \quad (A).$$

$$0 = -\Theta_A[1+3r_{ab}+3r_{ba}+6r_{ab}r_{ba}] - \Theta_B\left[\frac{2n+1}{n} + 6r_{ba} + 6r_{ba}^2\right] \quad (B).$$

Solving Joint Equations (A) and (B) Simultaneously

$$\Theta_A = \frac{M_{FAA}}{2E\frac{I_1}{h_1}} \cdot \frac{\left(\frac{2n+1}{n}\right) + 6r_{ba} + 6r_{ba}^2}{D}$$

$$\Theta_B = -\frac{M_{FAA}}{2E\frac{I_1}{h_1}} \cdot \frac{1+3r_{ab}+3r_{ba}+6r_{ab}r_{ba}}{D}$$

$$\frac{3\Delta}{h_1} = r_{ab}\left(\frac{2n+1}{n}\right) - r_{ba}(1-3r_{ab}+3r_{ba})$$

Where $D = \left[\frac{(2n+1)}{n} + 6r_{ba} + 6r_{ba}^2\right][N+2+6r_{ab}+6r_{ab}^2] - [1+3r_{ab}+3r_{ba}+6r_{ab}r_{ba}]^2$

End Moments

The end moments at top of floorbeam and at ends of bracket are obtained by inserting the above Θ and Δ values in the original equations used at the joints and shown in Fig. 9.

Note: Work Figs. 9 and 10 together

Fig. 10.—General Solution of Frame of Fig. 9.

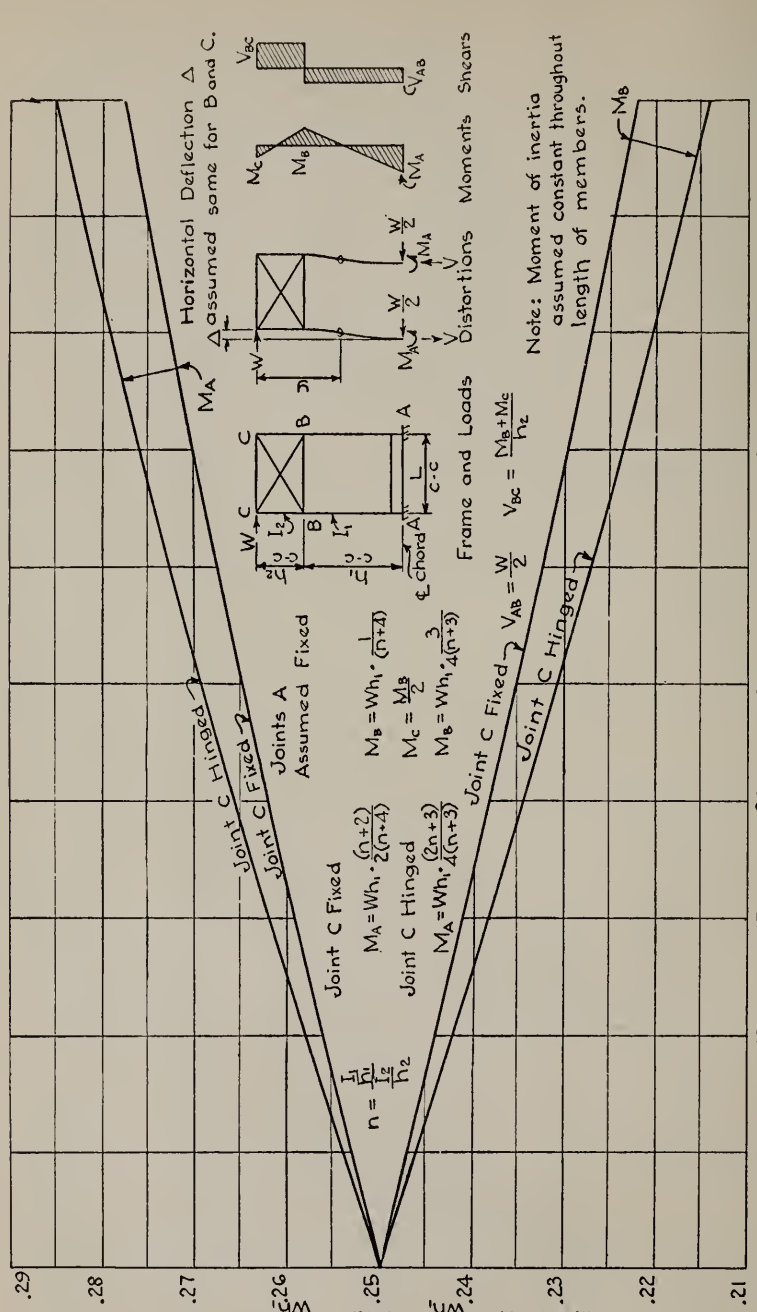


Fig. 11.—Stresses Due to Lateral Loads on Portals with Laterals, Standard Method.

Procedure

Joints C Assumed Fixed

It is assumed that the transverse force W is divided equally between the two portal columns. The product of the lateral force times the unbraced portal length, Wh_1, must equal the sum of the moments M_A and M_B in the two unbraced portal columns. This condition equation, together with the joint equilibrium equations, provides the means of determining the θ and Δ values.

Case 1. Joints A Assumed Fixed

Lateral Equilibrium Equation

$$M_{AB} = 2E\frac{I_1}{h_1}\left[\frac{3\Delta}{h_1} - \theta_B\right]$$

$$M_{BA} = 2E\frac{I_1}{h_1}\left[\frac{3\Delta}{h_1} - 2\theta_B\right]$$

$$M_{AB} + M_{BA} = 2E\frac{I_1}{h_1}\left[\frac{6\Delta}{h_1} - 3\theta_B\right] = \frac{Wh_1}{2} \quad (A).$$

Equilibrium Equation at Joint B

$$M_{BC} = 2E\frac{I_1}{nh_1}\left[-2\theta_B\right]$$

$$M_{BA} = 2E\frac{I_1}{h_1}\left[\frac{3\Delta}{h_1} - 2\theta_B\right]$$

$$0 = \frac{3\Delta}{h_1} - \theta_B \cdot \frac{2(n+1)}{n} \quad (B).$$

Solving Equations (A) and (B) Simultaneously

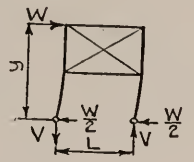
$$\theta_B = \frac{Wh_1}{2E\frac{I_1}{h_1}} \cdot \frac{n}{2(n+4)} \qquad \frac{3\Delta}{h_1} = \frac{Wh_1}{2E\frac{I_1}{h_1}} \cdot \frac{(n+1)}{(n+4)}$$

End Moments and Shears See Fig (11).

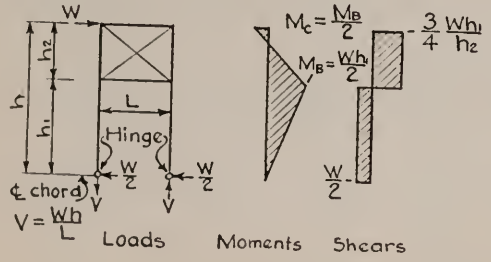
Overturn

Cut structure at points of inflection

$$V = \pm Wy \div L$$



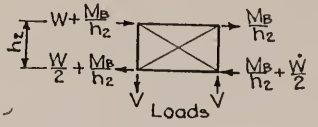
Case 2. Joints A Assumed Hinged



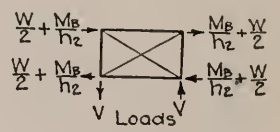
Note: Work Figs. 11 and 12 together.

Stresses in Bracing

Case 1. Lateral Load W Concentrated on one Truss.



Case 2. Lateral Load W Taken Equally by Trusses.



Note: The columns are cut at B and Moments M_B are replaced by the equivalent couples formed by the forces $M_B \div h_2$ which the columns deliver to bracing Moments M_C are not assumed to affect the bracing.

Case 3. Joints A Assumed Partially Restrained

In all cases the sum of M_A and M_B for both columns equals Wh_1. If point C is assumed to be fixed, M_C will be equal to $M_B \div 2$

Fig. 12.—General Solution of Frame of Fig. 11.

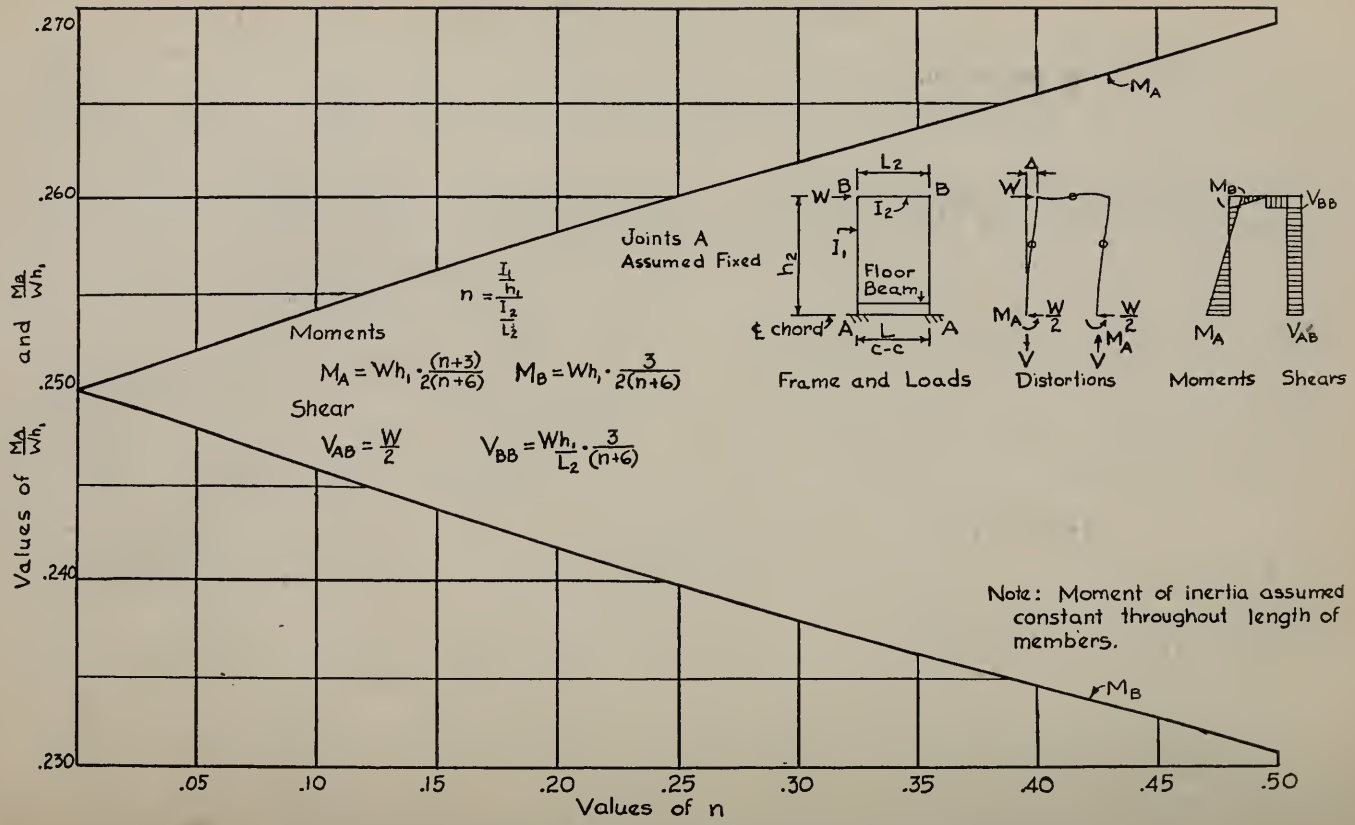
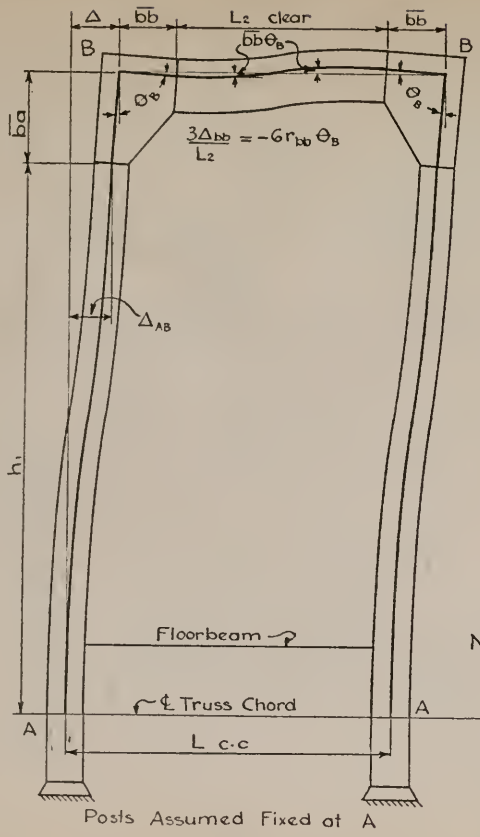


Fig. 13.—Stresses Due to Lateral Loads on Portals with Brackets, Standard Method.



Note: The correct values of θ_B and Δ_{AB} as shown in the figure, are obtained and the moments are then computed. See Fig. 15.

Moments

$$M_{AB} = +\frac{W}{2} \cdot \frac{h_1\left[\frac{n+6+24r_{bb}+24r_{bb}^2}{n}\right] + (h_1 + 2\overline{ba})}{D}$$

$$M_{BA} = +\frac{W}{2} \cdot \frac{h_1\left[\frac{n+6+24r_{bb}+24r_{bb}^2}{n}\right] - (h_1 + 2\overline{ba})}{D}$$

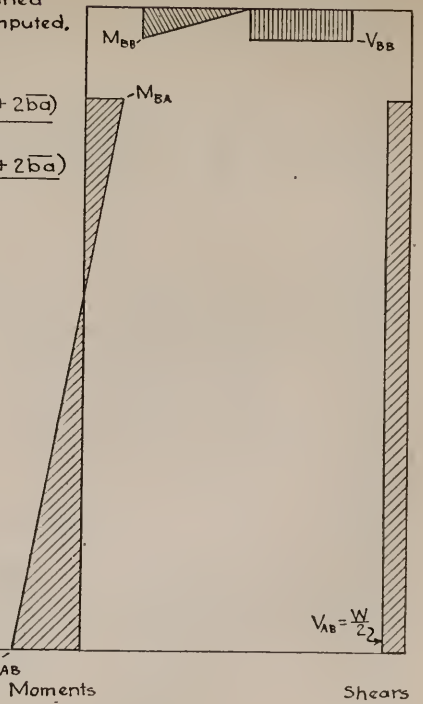
$$M_{BB} = -\frac{W}{n} \cdot \frac{3(1+2r_{bb})(h_1+2\overline{ba})}{D}$$

Where $D = 2\left[\frac{n+6+24r_{bb}+24r_{bb}^2}{n}\right]$

Shears

$$V_{BB} = \frac{2M_{BB}}{L_2}$$

Note: Work Figs. 14 and 15 Together.



Notation: See preceding figures.

Fig. 14.—Stresses Due to Lateral Loads on Portals with Brackets, Modified Method.

Procedure

The expression for M_{BB} (at edge of bracket) is written in terms of Θ and Δ values and the expression for the shear V_{BB} is obtained. The equilibrium equation for joint B is then written. The expressions for M_{AB} (at ℄ chord) and M_{BA} (at bottom of bracket) are written and their sum placed equal to $wh_1 \div 2$, giving the second equilibrium equation. Values of Θ and Δ may now be obtained.

Expression for V_{BB}

$$M_{BB} = 2E\frac{I_1}{nh_1}[-6r_{bb}\Theta_B - 3\Theta_B]$$

$$V_{BB} = 2E\frac{I_1}{nh_1}[-6r_{bb}\Theta_B - 3\Theta_B]2 \div L_2$$

$$\overline{bb}V_{BB} = 2E\frac{I_1}{nh_1}[-6\Theta_B(1+2r_{bb})]r_{bb}$$

$$\overline{ba}V_{AB} = \overline{ba}\frac{W}{2}$$

Equilibrium Equation at B

Joint B

$$M_{BB} = 2E\frac{I_1}{nh_1}[-6r_{bb}\Theta_B - 3\Theta_B]$$

$$\overline{bb}V_{BB} = 2E\frac{I_1}{nh_1}[-6r_{bb}\Theta_B - 12r_{bb}^2\Theta_B]$$

$$M_{BA} = 2E\frac{I_1}{h_1}\left[3\frac{\Delta_{AB}}{h_1} - 2\Theta_B\right]$$

$$\overline{ba}V_{AB} = \overline{ba}\frac{W}{2}$$

$$0 = \frac{\overline{ba}W}{4E\frac{I_1}{h_1}} + 3\frac{\Delta_{AB}}{h_1} - \Theta_B\left[\frac{2n+3+12r_{bb}+12r_{bb}^2}{n}\right] \quad (B).$$

Lateral Equilibrium Equation

$$M_{AB} = 2E\frac{I_1}{h_1}\left[\frac{3\Delta_{AB}}{h_1} - \Theta_B\right]$$

$$M_{BA} = 2E\frac{I_1}{h_1}\left[\frac{3\Delta_{AB}}{h_1} - 2\Theta_B\right]$$

$$M_{AB}+M_{BA} = 2E\frac{I_1}{h_1}\left[\frac{6\Delta_{AB}}{h_1} - 3\Theta_B\right] = \frac{Wh_1}{2} \quad (A).$$

Solving Equations (A) and (B) Simultaneously

$$\Theta_B = \frac{W}{2E\frac{I_1}{h_1}} \cdot \frac{(h_1+2\overline{ba})}{2\left[\frac{n+6+24r_{bb}+24r_{bb}^2}{n}\right]}$$

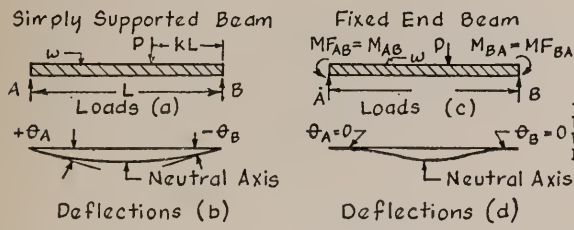
$$\frac{3\Delta_{AB}}{h_1} = \frac{W}{4E\frac{I_1}{h_1}} \cdot \frac{h_1\left[\frac{n+6+24r_{bb}+24r_{bb}^2}{n}\right] + 3(h_1+2\overline{ba})}{2\left[\frac{n+6+24r_{bb}+24r_{bb}^2}{n}\right]}$$

Fig. 15.—General Solution of Frame of Fig. 14.

Note: Work Figs. 14 and 15 together.

Procedure in computing fixed beam end moment for floor beam.

A simply supported beam carrying any loading may be converted into a fixed beam by applying end moments M_A and M_B which will rotate the ends of the simple beam back to their original positions, i.e., so that θ_A and θ_B become zero. See Figures 16 (a) to (d) incl. The angles θ_A and θ_B in (b) are conveniently obtained by the conjugate beam method. (1) The end moments in (c) are obtained by inserting the θ values in the slope deflection equations of Fig.1.



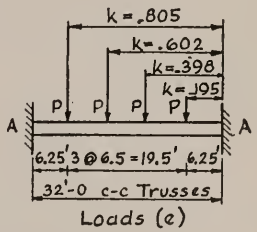
(1) Reference ; "Deflection of Beams by the Conjugate Beam Method" by H.M.Westergaard. Jour. Western Soc. of Engrs. Nov. 1921, pp.369-396 incl.

Beam with Constant I

The well known values for end moments in this case are ;

$$M_{FAB} = \frac{wL^2}{12} + PL(k^2 - k^3)$$

The beam and loading for the bridge in question are shown in Fig. 16(e). The computation for the fixed-beam end moment follows ;



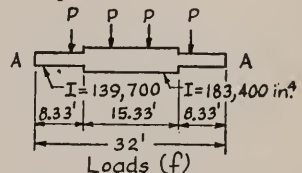
$$M_{FAA} = P\ 32 \left| \begin{array}{ll} k & k^2-k^3 \\ .195 & .0306 \\ .398 & .0954 \\ .602 & .1442 \\ .805 & .1214 \end{array} \right.$$

P=233 Kips
(See p. 467 of text)

.3916 = 12.531 P Ft. Kips = 2,915.5 Ft.Kips.

Beam with Variable I

The variation of the moment of inertia of the beam is considered. See "Procedure" above. The moment diagram of the simple beam, divided by EI, is the load on the conjugate beam. The reaction R_A of the conjugate beam is the θA of the simple beam.

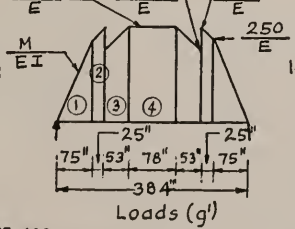


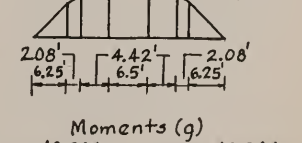
Reaction Computation

(1) 250 (75)½ = 9,375
(2) 270.5(25) = 6,762
(3) 255.4(53) = 13,536
(4) 289 (39) = 11,271

$R_A = 40,944 \div E$

$\theta_A = R_A = \frac{40,944}{E}$





Moment Coefficients

See Fig.3(b)

$K = \frac{8.33}{32.0} = 0.26 \qquad r = \frac{183,400}{139,700} = 1.314$

$C_{AB} = 2.103 \qquad C_{\overline{AB}} = 0.975$

Moment Calculation

$$M_{FAA} = 2E \frac{139,700}{32 \times 12}\left[(2.103 - 0.975) \times \frac{40,944}{E}\right]$$

$$= 33,620,000 \text{ in.lb.} = 2,802 \text{ ft.k.}$$

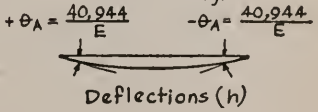
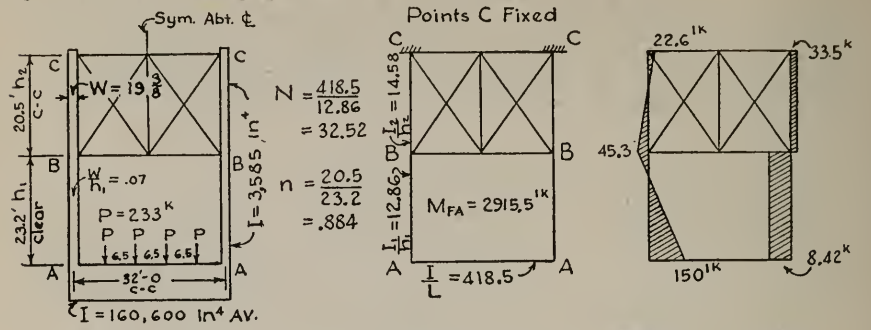


Fig. 16.—Example No. 1—Analysis of Stresses Due to Floor Beam Deflection in Bridge Span of Fig. 1 (a).

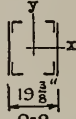
Rigid Frame Analysis at U_4-L_4 of Fig. 1(a) Standard Method. See Fig. 4.



Average I of Floorbeam $= \frac{2(8.33)139{,}700+(15.33)183{,}400}{32}$

$= 160{,}600$ in.⁴

Properties of Vertical



See p.476 in text.

Area = 45.25 in.²
r_x = 7.82 in.
r_y = 8.90
I/o_y = 370.2 in.³
L/r_x = 77 in AC
L/r_y = 31 in AB

Constants $(3n+4) = 6.652$

$2N(n+1)+(3n+4) = 129.19$

Moments $M_A = 2915.5 \times \frac{6.652}{129.19} = 150.0$ ft.k.

$M_B = 2915.5 \times \frac{2}{129.19} = 45.3$

$M_C = M_B \div 2 = 22.6$

Shears $V_{AB} = (150+45.3) \div 23.2 = 8.42$ k.

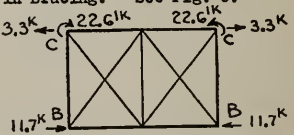
$V_{BC} = (45.3+22.6) \div 20.5 = 3.35$

Bending Unit Stresses in Vertical

At A $s = 150 \times 12 \div 370.2 = 4.86$ ksi

At B $s = 45.3 \times 12 \div 370.2 = 1.47$

Stresses in Bracing. See Fig. 5.



Design Stresses in Vertical

Allowable Axial Unit Stress = 13.52 ks. $15{,}000-\frac{1}{4}(77)^2$ Par.301 of AREA 1943 Specifications

Allowable Column Load = 612 k. 13.52×45.25

Shear Specified for Lacing = 16.8 k. $\frac{612}{100}\left[\frac{100}{41}+\frac{31}{100}\right]$ Par.420 of AREA 1943 Specifications

Ratio of Rigid Frame Stresses to Design Axial and Shear Stresses.

$\frac{\text{Unit Bending Stress at A}}{\text{Allowable Unit Axial Stress}} = \frac{4.86}{13.52} = 36\ \%$

$\frac{\text{Rigid Frame Shear in AB}}{\text{Design Shear by Par. 420}} = \frac{8.42}{16.8} = 50\ \%$

Note ; The lacing and connecting rivets are proportioned to carry 16.8 k. at specified working unit stresses and are over stressed 50 % by the added 8.42 k.

Correction for Horizontal Displacement Δ_{AB} at Top of Floorbeam (Approximate)

Stresses due to displacement Δ_{AB} at top of floorbeam may be added as a secondary operation. See Fig. 6.

$\theta_A = \frac{2{,}915.5 \times 12 \times 2(0.884+1)}{2\,E\,12.86 \times 129.19} = \frac{1{,}015{,}000}{2E\,12.86}$ radian

$M_A = M_B = 2E\,12.86\left[\frac{3 \times 44 \times 1{,}015{,}000}{278.4 \times 2E\,12.86}\right] = 481{,}500$ in.k.

$M_C = M_B \div 2 = 240{,}700$ in.k.

$V_{AB} = \frac{40.1+40.1}{23.2} = 3.46$ k. $\quad V_{BC} = \frac{40.1+20}{20.5} = 2.93$ k.

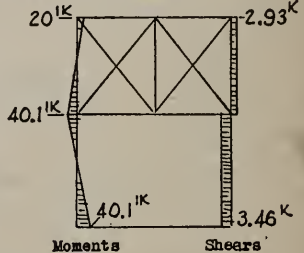


Fig. 17.—Example No. 1, Continued.

Rigid Frame Analysis at U_4-L_4 of Fig. 1 (a). Modified Method.

Constants $r_{ab} = \frac{3.67}{23.2} = .1582$ $N2(n+1) = 122.5$ $2(1+3r_{ab}) = 2.949$

$2(2+3r_{ab})+3n(1+r_{ab}) = 2(2.4746) + 2.652(1.1582) = 8.021$

D $2N(n+1)+(3n+4)+6r_{ab}(n+2)+3r_{ab}^2(n+4) = 132.25$

$65.04(1.884)+6.652+0.9492(2884)+0.075(4.884)$

Moments $M_{AA} = 2915.5\left[1 - \frac{122.5}{132.25}\right] = 215.0$ ft.k

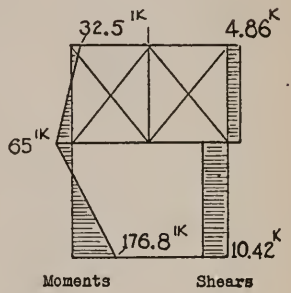
$M_{AB} = 2915.5 \times \frac{8.021}{132.25} = -176.8$

$M_{BA} = 2915.5 \times \frac{2.949}{132.25} = -65.0$

$M_{BC} = -M_{BA} = 65.0$ $M_{CB} = 32.5$

Shears $V_{AB} = (176.8+65) \div 23.2 = 10.42$ k

$V_{BC} = (65+32.5) \div 20.5 = 4.86$



Comparison of Results by Two Methods of Analysis

	M_A	V_{AB}
By Modified Method	176.8 ft.k	10.42 k
By Standard Method	150.0	8.42
Discrepancy	15 %	19 %

Fig. 18.—Example No. 1, Continued.

If investigation be made at U_2–L_2, where the vertical is stiffer and where the length h_2 is shorter than at U_4–L_4, it will be found that the shear is much greater, although the percentage ratio of rigid frame shear to design shear is about the same. That is to say, that much heavier lacing and connections will be required at U_2–L_2 than at U_4–L_4.

If the top strut is able to take the moment M_C the connections should be proportioned for this moment in the writer's judgment.

Example No. 2.—Frame with Top Strut and Brackets (Figs. 8, 9, 10, 19, 20)

The stresses in the verticals at U_3–L_3 of the 160-ft. single track span listed in Fig. 1 (b) are analyzed. Complete structural details are given in the Hool and Kinne text.[4]

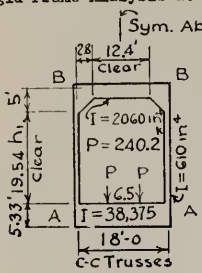
Analysis of the frame by both of these methods is shown in Fig. 19. The ratio of bending stress to axial stress is about the same as in the first example. The modified method gives results very close to the values obtained by the standard method except for the moment in the top strut. The M_B moment for the strut is low by the latter method since the effect of the shear V_{AB} on the joint rotation θ_B has not been included, that is, since moments at ends of brackets have been summed up to equal zero rather than moments at the center of the joint J_B. If however the bracing be made to include the brackets and the loads applied at lower end of brackets, as is done in Example 2, the results of the standard method will be very nearly the same as with the modified method.

Fig. 20 shows the computations for stresses where reinforcing plates have been added to the lower ends of the vertical hangers of U_3–L_3. The moment coefficients for the slope deflection equations are taken from Fig. 3 (a), either graphically or by computation and

(text continued on page 721)

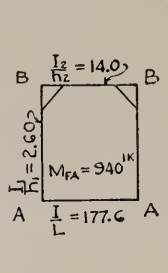
[4] Steel and Timber Structures, by Hool and Kinne.

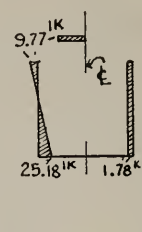
Rigid Frame Analysis at U_3-L_3. Standard Method. See Fig. 8. $M_{FAA} = \frac{1}{8}PL(k^2 - k^3)$



$N = \frac{177.6}{2.60} = 68.3$

$n = \frac{2.60}{14} = .186$





$k_1 = \frac{5.75}{18} = .32$

$k_2 = \frac{12.25}{18} = .68$

k	$k^2 - k^3$
.32	.0696
.68	.1480
	.2176

$M_{FAA} = P18(2176)$
$= P\ 3.915$
$= 940.0$ ft.k

See p. 336 of text

Frame and Loads — Stiffness Ratios — Moments — Shears — M_{FAA} Calculation

Constanta $(3n+2) = 2.557$

$N(2n+1) + (3n+2) = 96.177$

Moments $M_A = 940 \times \frac{2.557}{96.177} = 25.18$ ft.k

$M_B = 940 \times \frac{1}{96.177} = 9.77$

Properties of Vertical

See p.334 of text

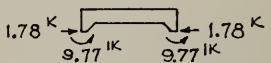
Area = 20.13 g.
= 16.21 n.
I/o y = 88.7 g.
= 71.3 n.

Shears $V_{AB} = \frac{25.18 + 9.77}{19.54} = 1.78$ k.

Bending Unit Stresses in Vertical

At A $s = 25.18 \times 12 \div 71.3 = 4.24$ ksi

Stresses in Bracing



Design Stresses in Vertical

Allowable unit tensile stress	16.00 ksi.	Par. 38 AREA 1920 Specifications
Actual Unit tensile stress	15.7	254.3 ÷ 16 p. 334 of text.

Ratio of Rigid Frame Stress to Design Stress

$\frac{\text{Unit Bending Stress at A}}{\text{Actual Axial Unit Stress}} = \frac{4.24}{15.7} = 27\ \%$

Note ; The vertical has excess section at the bottom of the bracket at B, since no holes occur in outstanding angle legs. Hence bending stress is not critical here.

Rigid Frame Analysis at U_3-L_3 by Modified Method. See Figs. 9 and 10.

Constants $r_{ab} = \frac{2.67}{19.54} = .1365$ $r_{ba} = \frac{5.0}{19.54} = .2557$

$\frac{(2n+1)}{n} + 6r_{ba} + 6r_{ba}^2 = 9.311$ $D = 9.311 \times 71.213 - (2.386)^2 = 656.4$

$\frac{(2+3r_{ab})}{n} + 3\left[1 + r_{ab}(1 + r_{ba}) + r_{ba}(2 + r_{ba})\right] = 12.970 + 5.242 = 18.212$

$\frac{(1+3r_{ab})}{n} - 3r_{ba}(1 + r_{ab} + r_{ba}) = 7.590 - 1.068 = 6.522$

$1 + 3r_{ab} + 3r_{ba} + 6r_{ab}r_{ba} = 2.386$ $N + 2 + 6r_{ab} + 6r_{ab} = 71.213$

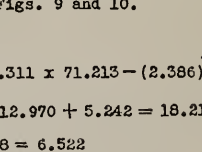
Moments $M_{AA} = 940\left[1 - 68.3 \times \frac{9.311}{656.4}\right] = +31.0$ ft.k.

$M_{AB} = 940 \times \frac{18.212}{656.4} = -27.1$

$M_{BA} = 940 \times \frac{6.522}{656.4} = -9.24$

$M_{BB} = 940 \times \frac{2.386 \div 0.186}{656.4} = +18.46$

Shears $V_{AB} = (27.1 + 9.2) \div 19.54 = 1.86$ k.



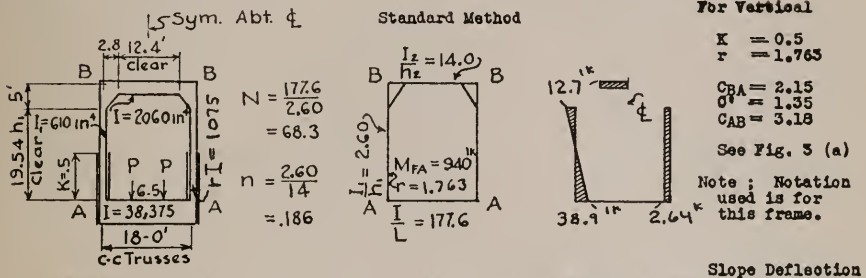
Moments Shears

Comparison of Results by Two Methods of Analysis

	M_{AB}	M_{BA}	M_{BB}	V_{AB}
By Modified Method	27.1 ft.k.	9.2 ft.k.	18.5 ft.k	1.86 k.
By Standard Method	25.2	9.8	9.8	1.78
Disorepancy	7 %	6 %	47 %	4 %

Fig. 19.—Example No. 2—Analysis of Stresses Due to Floor Beam Deflection in Bridge Span of Fig. 1(b).

Rigid Frame Analysis at U_3-L_3 of Fig.1(b). Vertical Reinforced for Bending.



Equilibrium Equations

Joint A
$$M_{AA} = +940 + 2EK\frac{I_1}{h_1}(-1.0\,\theta_A)$$
$$M_{AB} = 2E\frac{I_1}{h_1}(-3.18\,\theta_A - 1.35\,\theta_B)$$
$$0 = \frac{940}{2E\frac{I_1}{h_1}} - \theta_A(N+3.18) - 1.35\,\theta_B \quad (A)$$

Joint B
$$M_{BA} = 2E\frac{I_1}{h_1}(-2.15\,\theta_B - 1.35\,\theta_A)$$
$$M_{BB} = 2E\frac{I_1}{nh_1}(-1.0\,\theta_B)$$
$$0 = -\theta_B\left[\frac{2.15n+1}{n}\right] - 1.35\,\theta_A \quad (B)$$

Properties of Vertical

2 Pls. 12.5 x 3/8 added. See Fig.19.

Area = 29.50 g. = 24.09 n.
I/c_y = 148.2 g. = 121.0 n.

Solving Equations (A) and (B) and inserting the values of N and n ;

$$\theta_A = \frac{13.19}{2E\frac{I_1}{h_1}} \qquad \theta_B = -\frac{2.363}{2E\frac{I_1}{h_1}}$$

Note ; Multiply above θ values by 12 x 1000 to obtain true values in radians.

Moments

Inserting the values of θ found above in the slope deflection equations written at the joints above the final end moments for the members are obtained. A check on the accuracy of the work is also secured.

Note ; Since the values of $2EI_1 \div h_1$ outside the parentheses containing the θs in the slope deflection equations will cancel the same values in the denominators of the θ expressions, this quantity $2EI_1 \div h_1$ may be omitted entirely in the calculations of final end moments.

Joint A
$M_{AA} = +940 + 68.3(-13.19) = +39.0$ ft.k.
$M_{AB} = -3.18(13.19) - 1.35(-2.363) = -38.8$ } Check

Joint B
$M_{BA} = -2.15(-2.363) - 1.35(13.19) = -12.7$
$M_{BB} = -1.0(-2.363) \div 0.186 = +12.7$ } Check

Shear $V_{AB} = (38.9 + 12.7) \div 19.54 = 2.64$ k.

Combined Unit Stress in Vertical

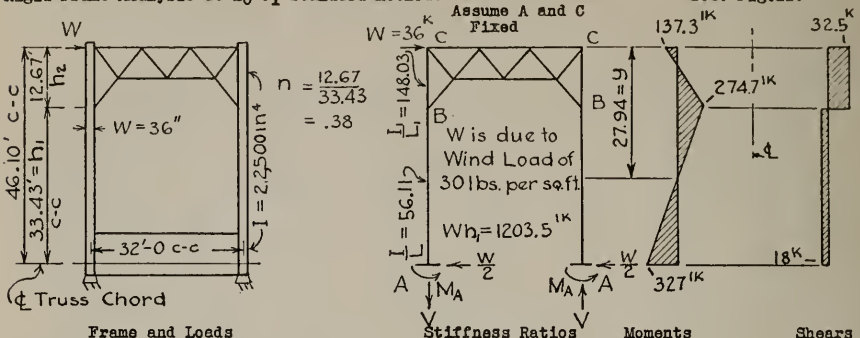
Unit bending stress in tension at A $s = 38.9 \times 12 \div 121.0 = 3.84$ ksi.

Unit tensile axial stress in tension $P/A = 254.3 \div 24.09 = 10.59$

Total combined unit tensile stress at A $= 14.43$

Fig. 20.—Example No. 2, Continued.

Rigid Frame Analysis at L_0-U_1 Standard Method. See. Fig.11.



Constants $n+2 = 2.38$ $n+4 = 4.38$

Moments
$M_A = 1203.5 \times \frac{2.38}{2(4.38)} = 327.0$ ft.k.
$M_B = 1203.5 \times \frac{1}{4.38} = 274.7$
Check $Wh_1 \div 2 = 601.7$
$M_C = M_B \div 2 = 137.3$

Shears
$V_{AB} = W \div 2 = 18.0$ k.
$V_{BC} = \frac{274.7+137.3}{12.67} = 32.5$

Bending Unit Stresses in Post

At B $s = 274.7 \times 12 \div 1250 = 2.64$ ksi.

At A Excess section is provided by gussets

Properties of Post

See p.474 in text

Area = 161.2 in.²
r x = 10.9 in.
r y = 11.8
I/c y = 1250.0 in.³
L/r x = 51 in AC
L/r y = 35 in AB
L/r y = 13 in BC

Overturn

$V = 36 \times 27.94 \div 32 = 31.4$ k.

Overturn Unit Axial Stress

$P/A = 31.4 \div 161.2 = 0.20$ ksi.

Design Stresses in Post

Allowable unit axial stress = 14.45 ksi. $15{,}000 - \frac{1}{4}(51)^2$ — Par. 301 of AREA 1943 Spec.

Allowable column load = 2330 k. 14.45×161.2

Shear specified for lacing = 59.8 k. for AB $\frac{2330}{100}\left[\frac{100}{45}+\frac{35}{100}\right]$ — Par. 420 of AREA 1943 Spec.

= 104.4 for BC $\frac{2330}{100}\left[\frac{100}{23}+\frac{13}{100}\right]$

Ratio of Rigid Frame Stresses to Design Axial and Shear Stresses

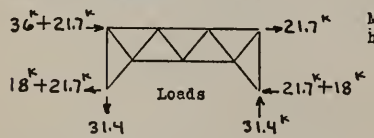
$\frac{\text{Unit Bending Stress at B}}{\text{Allowable Unit Axial Stress}} = \frac{2.64+0.20}{14.45} = 20\ \%$

$\frac{\text{Rigid Frame Shear in AB}}{\text{Design Shear by Par. 420}} = \frac{18}{59.8} = 30\ \%$

$\frac{\text{Rigid Frame Shear in BC}}{\text{Design Shear by Par. 420}} = \frac{32.5}{104.4} = 31\ \%$

Note ; To properly carry the shears the lacing and connecting rivets should be nearly twice as strong in BC as in AB.

Stresses in Bracing See Fig.12.



$\frac{M_B}{h_2} = \frac{274.7}{12.67} = 21.7$ k.

Fig. 21.—Example No. 3—Analysis of Portal Stresses Due to Lateral Loads in Bridge of Fig. 1 (a).

(text continued from page 717)
the procedure is otherwise as outlined in Fig. 5. Note that the A and B notation used in the frame in Fig. 20 is not the same as used in Fig. 3.

Lateral Loads on Portals

The controlling factor in this frame is largely the degree of fixity of the joint at A. The limiting value of M_A will usually be the product of the load in the end post times half the width of the member or gusset, where it bears on the pin of the shoe. This condition will frequently be sufficient to make the end post fully fixed. For recent structures, representing good modern practice, the end floorbeam will usually be rigidly connected to the gussets at the L_0 joint and this will further stiffen the joint against rotation. For older structures without rigidly connected end floorbeams, particularly short spans where the dead load stress in the end post is small, a condition much less than fixity probably occurs. In any event the sum of the end moments at A and at B on the two posts must equal the product of the wind times the unbraced column length, i.e., Wh_1 in Fig. 11. If the joint at A is not fully fixed so that the moment M_A is taken as the post load times half the member width at the pin, the moments on the two posts will no longer be identical, since the overturn adds to one column load while it relieves the other. This means that the points of inflection of the posts will not be on the same level and the problem becomes more tedious. This condition occurs frequently during erection while the dead load stress in the end post is small.

Example No. 3.—Frame with Sway Bracing (Figs. 11, 12, 21)

The stresses in the posts L_0U_1 of the 300-ft. span of Fig. 1 (a) are analyzed.

The joint C is probably more nearly fixed than hinged, not from support of the bracing but from the rigid connection to other truss members at the hip joint. It is usually on the safe side to assume C fixed and it simplifies the analysis. The critical stress in bending usually occurs at B since the gussets offer added material at A in a well designed joint. With C assumed as fixed the bending moment at B is larger than with C taken as hinged.

The shear in the upper part of the post is usually greater than in the lower, as is illustrated in this example. This means that much heavier lacing is required in that section than below. The shears set up by such lateral action are quite substantial.

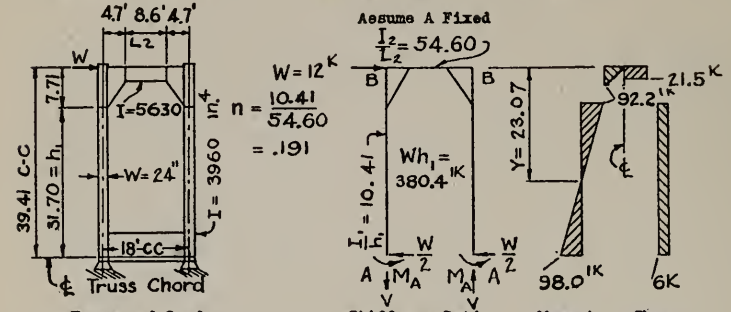
The overturn is easily computed by cutting the structure at the points of inflection, in the usual manner. The stresses in the bracing are conveniently computed by cutting the end post at the point B and replacing the moment it delivers to the bracing frame by the couple formed by the forces $M_B \div h_2$ as shown in Fig. 12. This arrangement delivers to the points B and C precisely the loads which the end post delivers in the bridge. In most cases the top strut will not be good for the moment M_C and this moment should not be assumed taken by the bracing in that case, but by the rigid connection to the other truss members, as noted above. Usually the lateral load W would be delivered to one truss, since in many cases the top lateral bracing (horizontal) beyond the hip joint will not take much compression. In any event assuming W at the near truss gives greater stresses in the top strut and is on the safe side.

Example No. 4.—Portal with Top Strut and Brackets (Figs. 13, 14, 15, 22, 23)

The stresses in the posts L_0U_1 of the 160-ft. span of Fig. 1 (b) are analyzed.

In this bridge the restraining moment at A due to dead load stress in the end post is nearly enough to fix the joint. In addition the end floorbeam is substantially built and rigidly connected to the L_0 joint; hence the joint A has been assumed as fixed.

Rigid Frame Analysis at L_0-U_1. Standard Method. See. Fig. 13.



Constants $n+3 = 3.19$ $2(n+6) = 12.38$

Moments $M_A = 380.4 \times \frac{3.19}{12.38} = 98.0$ ft.k

$M_B = 380.4 \times \frac{3}{12.38} = 92.2$

Shears $V_{AB} = W \div 2 = 6.0$ k.

$V_{BB} = 92.3 \times 2 \div 8.6 = 21.5$

Properties of Post

Area = 55.55 $in.^2$
r_x = 7.70 in.
r_y = 8.45
I/o_4 = 330. $in.^3$
L/r_x = 62
L/r_y = 45

See p.332 in text

Overturn Unit Axial Stress

$P/A = 15.38 \quad 55.55 = 0.28$ ksi.

Overturn

$V = 12 \times 23.07 \div 18 = 15.38$ k.

Bending Unit Stress in Post

At B $s = 92.2 \times 12 \div 330 = 3.36$ ksi. At A Gussets provide excess section.

Design Stresses in Post

Allowable Unit axial stress	= 11.93 ksi.	15,000 −50(62)	Par. 38 of AREA 1920 Specifications.
Allowable column load	= 661. k.	11.93 x 55.55	
Shear specified for lacing	= 16.5 k.	0.025 x 661	Par.69 of AREA 1920 Specifications

Ratio of Rigid Frame Stresses to Design Axial and Shear Stresses

$\frac{\text{Unit Bending Stress at B}}{\text{Allowable Unit Axial Stress}} = \frac{3.36+0.28}{11.93} = 30\ \%$

$\frac{\text{Rigid Frame Shear in AB}}{\text{Design Shear by Par. 69}} = \frac{6}{16.5} = 36\ \%$

Stresses in Bracing

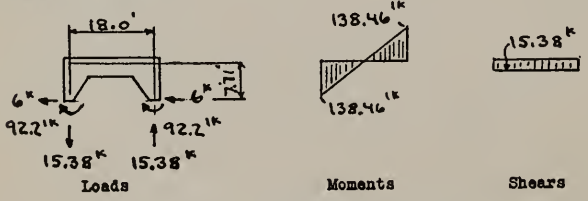


Fig. 22.—Example No. 4—Analysis of Portal Stresses Due to Lateral Loads in Bridge of Fig. 1 (b).

Rigid Frame Analysis at L_0-U_1 of Fig. 1(b) . Modified Method. See Fig. 14

Constants $r_{bb} = \frac{4.7}{8.6} = 0.546$ $h_1 + 2_{\overline{ba}} = 565.4$ in.

$\frac{(n+6+24r_{bb}+24r_{bb}^2)}{n} = 138.65$ $3(1+2r_{bb}) = 6.276$ $D = 277.3$

Moments $M_{AB} = \frac{12}{2} \times \frac{380.4 \times 138.65 + 565.4}{277.3} = 1154$ in.k $= 96.2$ ft.k.

$M_{BA} = \frac{12}{2} \times \frac{380.4 \times 138.65 - 565.4}{277.3} = 1128 = 94.0$

$= 380.4 \div 2$ Check

$M_{BB} = \frac{12}{.191} \times \frac{6.276 \times 565.4}{277.3} = -804 = -67.0$

Shears $V_{AB} = 12 \div 2 = 6.0$ k.

$V_{BA} = (67 \times 2) \div 8.6 = 15.6$ k.

Overturn $V = 12 \times 23.39 \div 18 = 15.59$ k.

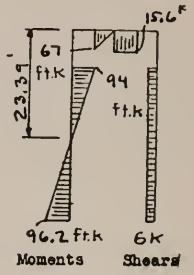


Fig. 23.—Example No. 4, Continued.

Comparison of the results of the standard method with the modified method shows the moment in the top strut to be too high by the former. If, however, the loads are applied to the strut through the brackets, as shown in Fig. 22, the results will be very nearly correct.

Conclusions

In many instances the stresses set up by rigid frame action for the cases discussed will be considerably larger, compared to the design stress, than the values shown in the modern bridges analyzed here.

It is the writer's opinion that these stresses should always be computed and both main material and details proportioned in a rational manner and that the specifications should specifically provide for this analysis.

The Effect of the Ratio of Wheel Diameter to Wheel Load on Extent of Rail Damage

By N. J. Alleman

Special Research Associate Professor of Engineering Materials, University of Illinois

FOREWORD BY G. M. MAGEE

This is a report of progress on item 3 of the research projects of the Joint Committee on Relation Between Track and Equipment of the Association of American Railroads, namely, studies of pressure as affected by the area of contact between wheel and rail. The joint committee, in which both the Engineering and Mechanical divisions of the AAR are represented, consists of the following:

Mechanical Division

Kenneth Cartwright (chairman), chief mechanical engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.

A. G. Hoppe, assistant chief mechanical officer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Milwaukee, Wis.

W. I. Cantley, mechanical engineer, Mechanical Division, Association of American Railroads, Chicago

V. R. Hawthorne, executive vice-chairman, Mechanical Division, Association of American Railroads, Chicago

Engineering Division

E. M. Hastings, chief engineer, Richmond, Fredericksburg & Potomac Railroad, Richmond, Va.

W. J. Burton, assistant to chief engineer, Missouri Pacific Railroad, St. Louis, Mo.

G. M. Magee, research engineer, Engineering Division, Association of American Railroads, Chicago

W. S. Lacher, secretary, Engineering Division, Association of American Railroads, Chicago

One phase of this investigation involves the conduct of rolling load tests of rails subjected to wheels of various diameters and loads. This work is being conducted at the University of Illinois under the direction of Professor N. J. Alleman.

Résumé

The first progress report of tests on the effect of wheel diameter on wheel load was published in the AREA Proceedings, Vol. 45, 1944, page 3 of the monograph section.

Results were reported of tests using flangeless 33-in. and 50-in. diameter wheels, with various loads, on rails with artificial defects in the form of drilled holes in the heads. Also included were the results of tests using shatter cracked rails from a hydrogen treated ingot. For both types of tests an attempt was made to obtain a comparison of the number of cycles for failure of the rail with each wheel.

The rails with imposed defects developed horizontal split heads at an indefinite number of cycles. The shatter cracked rails developed transverse fissures at a definite number of cycles; however, it was judged that the cycles for failure in each case were determined to a considerable extent by the depth of the particular crack from which

Bulletin 453, June–July 1945.

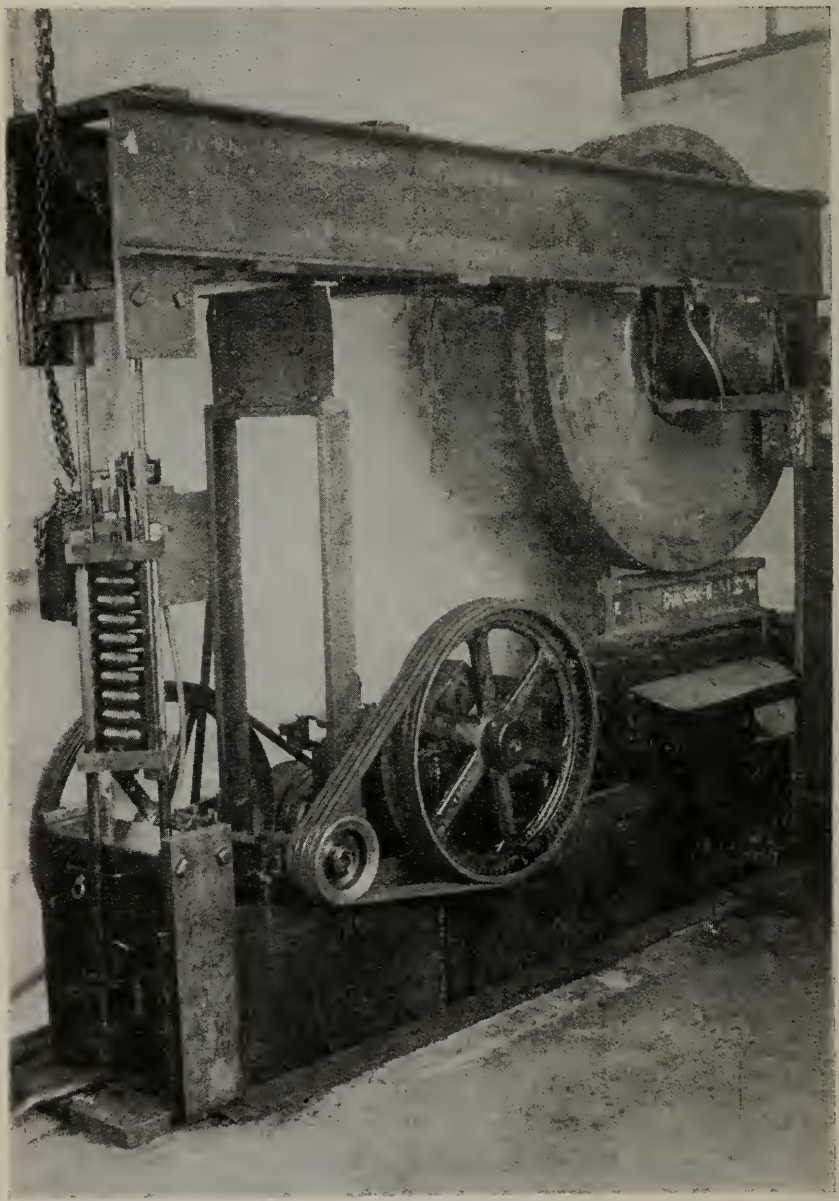


Fig. 1.—Rolling Load Machine—12-in. Stroke 50-in. Wheel Installed.

Fig. 2.—Etched Section on Rail 761 Showing Pipe.

the fissure developed. To obtain a load relationship between the two wheel sizes by this method a considerable number of tests should be run so that the wheels could be judged on the bases of the number of cycles to failure of the rails with fissure nuclei at the same depth.

A third type of test was made in which the rail was rolled for a given number of cycles under a given load, then cut up and a hardness survey taken over the rail head.

Preliminary tests with a 75,000-lb. load indicated that the maximum hardness was at a distance of about 0.2 in. below the tread, and that the 33-in. wheel work hardened the head to a higher maximum hardness and to a greater total depth than did the 50-in. wheel.

Wheel Loads and Testing Machine

As the tests for depth of work hardening appeared to be the more promising, further tests were made using loads of 75,000, 60,000 and 45,000 lb., for each wheel. This report covers these tests; also included are the results of a hardness survey on a rail from service, and tests made on rails with "mutilated" heads in which the wheel path was reduced to one inch in width.

Fig. 1 shows the 12-in. stroke rolling load machine in which the tests are made with the 50-in. wheel installed. The testing speed is 60 cycles per minute, the specimen length is 30 in.

Test Results

The data for the individual tests are listed in Table 1. Table 2 shows the hardness results for each rail. Comparison tests, (rails rolled in the machine at the same load) were cut from adjacent locations in the same rail. Rails 765, 761 and 794 were cut from the front end of 39-ft. A rails and were from different mills. A piped condition was observed in the web of rail 761 during the test.

Table 1.—Wheel Size Tests—131-lb. Rail

Tested in 12-in. Stroke Rolling Load Machine

Rail Lab. no.	*Load lb.*	*Support*	*Cycles*	*Tons Millions*	*Wheel Diam. in.*	*Vertical Wear Inches in 100,000,000 tons*	*Remarks*
350	112-lb. rail from service I.C.R.R. (kinked after engine tests) Approx. 12,000,000 tons						
763–1	75,000	rigid	1,333,000	100	50	0.0253	
765–1	75,000	beam*	1,333,000	100	50	0.0384	
765–2	75,000	beam*	1,333,000	100	33	0.0086	
761–1	60,000	beam*	1,666,700	100	50	0.0171	Pipe extended into head
761–2	60,000	beam*	1,666,700	100	33	0.0262	Pipe extended into head
794–1	45,000	beam*	2,222,000	100	50	0.0136	
794–2	45,000	beam*	2,222,000	100	33	0.0058	

* Simple beam loading, 24-in. span. Maximum compressive bending stress on tread at midspan: 75,000 lb.—19,900 psi; 60,000 lb.—15,400 psi; 45,000 lb.—12,000 psi.

Table 2.—Hardness Results on Rails

Rail Lab. no.	*Brinell Readings on Center Line of Tread** Wheel passages—millions of tons* 0	10	40	100	*Rockwell C Hardness On Tread Before Test*	*After Test*	*On Diagonal Section Max.*	*Depth, in.*
350	Tread Center Line—272; 7/8 in. to gage side–290						34.6	0.04
763–1	231			283			v28.0	0.20
765–1	208		281	284	9	23	27.4	0.10
765–2	217		236	238	9	15	31.8	0.15
761–1	216	228		242		15.0	25.0	0.13
761–2	208	228	229	293		21.6	30.5	0.12
794–1	268	263	284	311	11.2	25.0	31.5	0.10
794–2	239	262	273	278	11.2	19.0	32.0	0.12

v — Vickers diamond pyramid hardness—50 kg.
** — Test surface filed smooth.

Hardness specimens were prepared by roughing out the blanks on a band saw, finishing to dimensions on a shaper and finally preparing the test surface on a surface grinder. Because of the possibility that the method of preparing specimens could have a decided effect on the hardness survey, a duplicate section from an untested location was usually prepared for purposes of comparison.

For both specimens, 761–1 and 761–2, hard spots, probably resulting from a segregated condition, were encountered in the head during the preparation of the hardness specimens. These spots, located directly above the pipe in the web (see Fig. 2), repeatedly broke off the point of the machine tool during the machining process. Too much weight cannot be given to the data from rail specimens 761 due to this abnormal condition of the rail head.

Work Hardening on Rail from Service

Fig. 3 shows the effect of traffic on work hardening, as measured by Rockwell C hardness, of a 112-lb. rail No. 350, removed from service on the Illinois Central because of kinking, a condition developing from a series of high speed engine tests near Thomasboro, Ill. The hardness section was not near a kink and the traffic over the rail was approximately 12,000,000 tons.

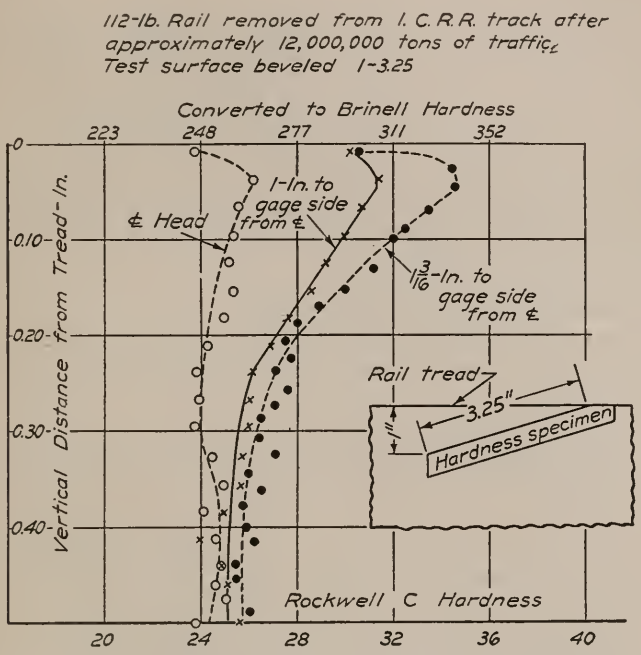


Fig. 3.—Depth-Hardness Survey on Rail Removed from Track.

The maximum hardness on the test section was Rockwell C 34.6 on a vertical gage line 1 3/16 in. in from the center of the head and at a depth of 0.04 in. The rail head appears to be work hardened to a depth of ¼ in.

On a vertical line 1 in. to the gage side the maximum hardness was Rockwell C (Rc) 31.5 at a depth of about 0.04 in.

Minimum Spacing of Hardness Indentation

For accurate results it is recommended that Rockwell impressions be spaced not closer than 2.5 times the diameter of the impression. Since diameters are approximately 0.03 in. for hardness readings of Rockwell C 25–30, the minimum spacing is approximately 0.075 in. With this spacing, readings on a vertical face of the rail head are too far apart to get an accurate picture of the hardness variation with depth; consequently the practice was adopted of cutting the test surface at an angle with the tread of the rail. Readings taken on a transverse face appear to check well with those taken on a beveled face.

Brinell Hardness on Tread

Readings on the tread of rail 350, with 1/64 in. of surface ground off to get a smooth testing surface (Table 2), showed a Brinell hardness of 272 at the center of the tread and Brinell 290 at 7/8 in. to the gage side from the middle of the tread.

Fatigue specimens 1/4 in. in diameter cut adjacent to the head of the rail gave an endurance limit of 72,000 psi. Two tension specimens from the same location gave the following results:

No.	*Tensile Strength*	*Yield Strength 0.2% Set*	*Elongation 2-in. g. l.*	*Reduction of Area*
	lb. per sq. in.		*Percent*	*Percent*
350C	141,500	80,200	8.5	23.8
350G	136,000	79,100	9.0	34.6

Fatigue tests on 20 rails free from shatter cracks, reported by the Rails Investigation on 0.3-in. diameter specimens cut from rail heads and tested in reversed bending, gave endurance limits ranging from 43,000 to 58,000 psi. Of the 20 endurance limits obtained, 14 were between 50,000 and 56,000 psi.

Rail Tread Hardness Developed in Service

Table 3 compiled from data taken on the Chesapeake & Ohio test track at Carey, Ohio, shows the traffic (tonnage) necessary to develop maximum hardness on the rail tread.

Table 3.—Hardness Results on Non End-Hardened Rails

C. & O. Test Track near Carey, Ohio. Readings on tread about 3/8 in. from end of rail

Number of Readings	*Brinell Hardness*		*Tons of Traffic (Millions)*
	Range	*Average*	
76	234–261	246	0.
51	241–277	255	1.85
94	256–295	273	21.5
96	271–307	284	38.
85	266–307	286	59.
79	269–306	287	77.

The results of these field tests show that the Brinell hardness on the rail tread reached a maximum at 38,000,000 tons. The surface was filed smooth for the readings at zero tonnage. For the later readings the surface was adequately smooth and required no polishing.

Depth Hardness Surveys

Figs. 4, 5 and 6 show the results of comparative tests run with the 50 and 33-in. wheels at loads of 75,000, 60,000 and 45,000 lb. The tests were run until the wheel load tonnage was 100 million tons. Under the conditions of testing (a flangeless, cylindrical wheel rolling on the center of the rail tread), it is considered that 100 million tons would be sufficient to develop maximum work hardening in the rail head. This view is supported by the fact that vertical wear had ceased to increase and Brinell readings on the rail tread had reached a maximum.

Fig. 4 shows the results of the depth-hardness survey on rail 765 in the untested condition and after testing under a 75,000-lb. load. After testing with the 50-in. wheel,

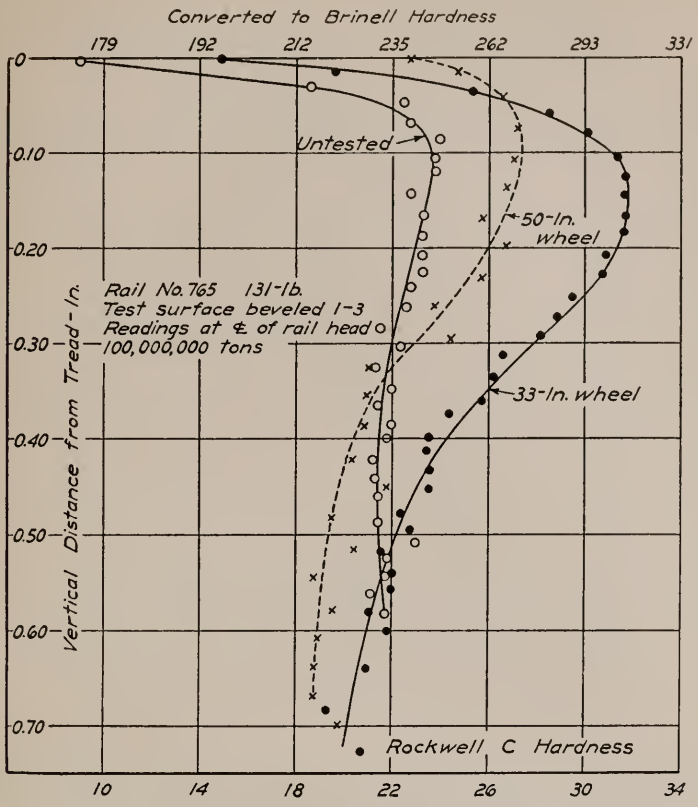


Fig. 4.—Depth-Hardness Survey after Testing with a 75,000-lb. Wheel Load.

a maximum hardness of Rockwell C 27.4 was found at a depth of 0.10 in. After testing with the 33-in. wheel, a maximum hardness of Rc 31.8 at a depth of 0.15 in. was found.

The total depth of work hardening appears to be greater for the 33-in. wheel test, approximately 0.5 in. For the 50-in. wheel test some increase of hardness was noted as deep as 0.3 in. A surface hardness of Rc 9 before testing was increased to Rc 15 by the 33-in. wheel and to Rc 23 by the 50-in. wheel.

Curves showing the depth hardness survey for rail 761 tested under a 60,000-lb. load are presented in Fig. 5. The 50-in. wheel work hardened the surface to Rc 15 with a maximum hardness of Rc 25 at a depth of 0.125 in. For the 33-in. wheel test the surface hardness was Rc 21.6 and the maximum Rc 30.5 also at a depth of 0.125 in.

Since a piped condition with attendant segregation was noted in this rail, hardness results are of doubtful validity. A bulge was noted along the edge of the wheel path near midstroke, indicating that the wheel canted slightly.

The results of the hardness survey on rail 794 tested at 45,000 lb. are shown in Fig. 6. Under this load the 50-in. wheel test showed the higher hardness on the surface Rc 25 as against Rc 19 for the smaller wheel. A maximum hardness of Rc 32 was noted

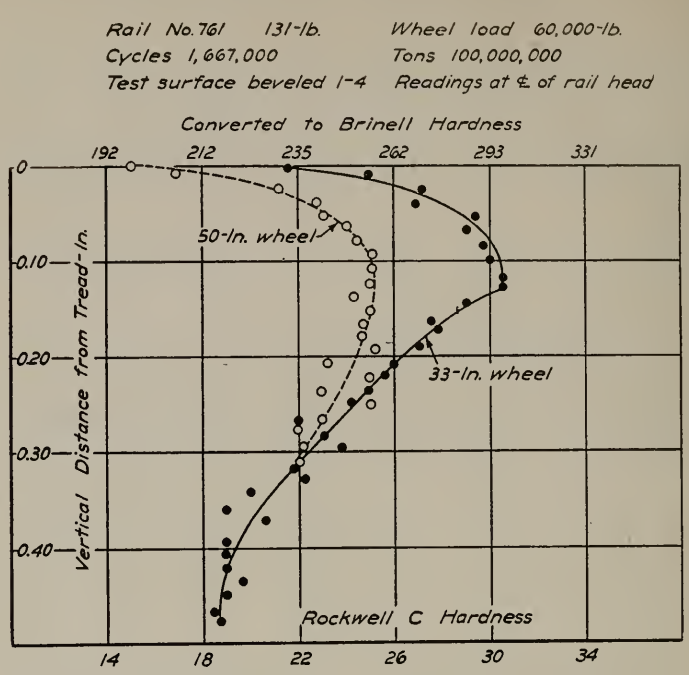


Fig. 5.—Depth-Hardness Survey after Testing with a 60,000-lb. Wheel Load.

for the 33-in. wheel as against Rc 31.5 for the larger wheel. The depth to maximum hardness appears to be slightly greater for the small wheel, with total depth of hardening about the same, namely 0.30 in.

A hardness survey on the vertical face of a transverse section of rail 794–1, 50-in. wheel test, showed a minimum hardness of Rc 24 at a depth of 0.60 in., the hardness increasing to a constant value of Rc 27–28 at a depth of 1.3 in.

Wear

Fig. 7 shows the profiles along the center of the rail tread for the three specimens tested with the 50-in. wheel. Vertical wear is a maximum near midlength of the 12-in. wheel path.

Fig. 8 shows, for the six tests made, the vertical wear at midstroke plotted against equivalent tonnage for the six tests. Note that vertical wear has reached a maximum in most cases at 80,000,000 tons. The large variations for the first few cycles are undoubtedly due to the initially rough, pitted and scaly condition of the rail treads. An attempt was made to smooth the surface with abrasive cloth. However, the mill scale, removable only by grinding, was not eliminated but broke loose after a few cycles of testing, leaving a pebbled surface which soon became smooth.

For the 75,000-lb. and 45,000-lb. load tests, wear values were found to be greater with the 50-in. wheel. A rapid increase in wear took place on rail 761 under a 60,000-lb.

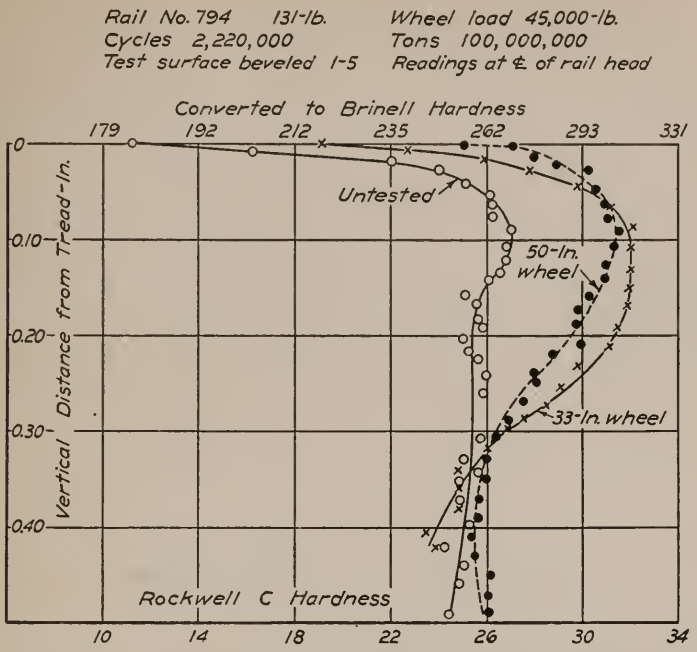


Fig. 6.—Depth-Hardness Survey after Testing with a 45,000-lb. Wheel Load.

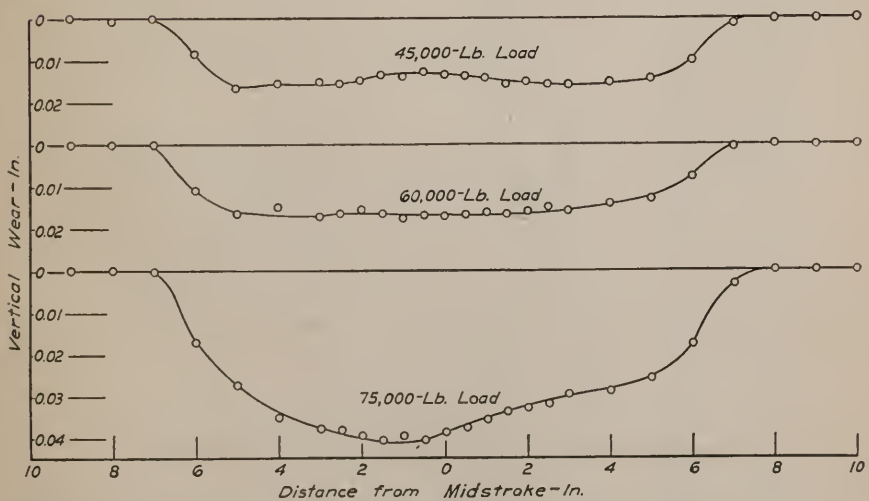


Fig. 7.—Profiles at Center of Rail Treads after Testing; 100,000 Tons, 50-in. Wheel.

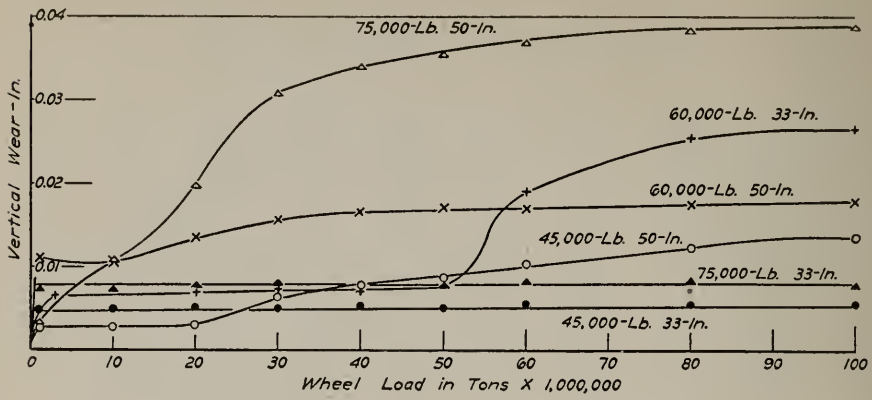


Fig. 8.—Vertical Wear at Center of Tread at Midstroke.

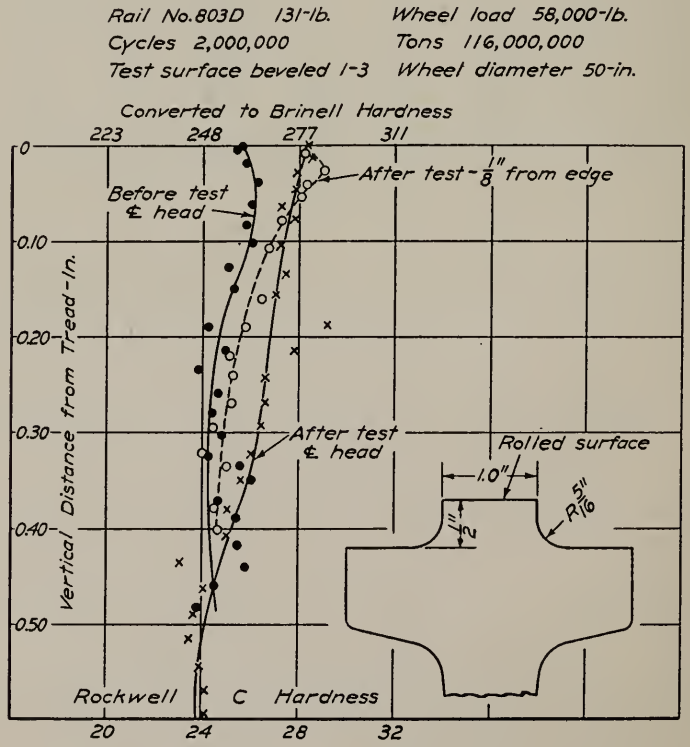


Fig. 9.—Depth-Hardness Survey on Rail 803D with "Mutilated" Head.

load on the 33-in. wheel, at 55,000,000 tons. As previously noted, results on this rail were probably affected by a piped condition.

Since most of the wear values are of the order of 1/64 in., not too much weight should be given to the slight differences as measured in these tests.

Tests on Rails with "Mutilated" Head

In connection with the investigation of shelly rails, a few tests were made in the rolling load machines with rail that had the tread reduced to one inch in width by machining off the corners of the head. The section of the reduced or "mutilated" head is shown in Fig. 9. To eliminate the decarburized surface on the tread, 1/16-in. of metal was removed. Preliminary tests with this shape of specimen gave variable results which were traceable to the roughness of the machined surfaces of the sides and radii of the reduced section. Grinding of the sides and radii to provide a smoother surface, removed the stress raisers and eliminated the "scatter" of results.

Table 4.—Wheel Size Tests on Rails with "Mutilated" Heads

Wheel path 1 in. wide, ½ in. high, 5/16 in. fillet radius, 1/16 in. of top surface removed
Surface of tread, sides and fillet ground smooth

Rail Lab. No.	*Load lb.*	*Wheel diam. in.*	*Machine stroke in.*	*Cycles*	*Tons millions*	*Vertical wear* in.*	*Path width in.*	*B.h.n.*
				0		0	0.989	270
803–A	53,000	50	12	503,000		0.0047	1.010	
				1,002,600		0.0056	1.012	
				1,500,000		0.0052	1.013	
				2,000,000	106	0.0053	1.013	280
803–D	58,000	50	12	0		0	1.003	275
				500,200		0.0067	1.056	
				1,001,000		0.0068	1.065	
				1,500,000		0.0080	1,066	
				2,000,000	116	0.0084	1.073	298
803–E	58,000	50	12	0		0	0.997	271
				500,800		0.0073	1.052	
				1,002,000		0.0081	1.056	
				1,500,000		0.0096	1.060	
				2,000,000	116	0.0107	1.066	297
803–5	63,000	50	12	0		0	1.000	274
				221,600		0.0215	1.048	
				245,700	15.6	0.0325	1.061	279
						Cracked		
803–C	63,000	50	12	0		0	0.995	276
				500,000		0.0226		
				699,000	44.0	0.0238	1.198	292
						Cracked		
804–A	50,000	33	7	0		0	1.003	284
				504,700		0.0085	1.042	
				1,000,400		0.0168	1.081	309
				1,079,700	54.0	Cracked out ⅛" deep		
804–B	50,000	33	7	0		0	0.999	281
				501,000		0.0073	1.028	
				1,005,100		0.0083	1.038	
				1,088,700	54.5	0.0105	1.045	302
						Cracked		

* Center of tread at midstroke.

Table 4 gives the results of five tests with the 50-in. wheel on the 12-in. stroke machine, and two results with a 33-in. wheel on a 7-in. stroke machine. All tests were on A rails from the same heat.

The results show that with the 50-in. wheel a load of 58,000 lb. can be carried 2,000,000 cycles (equivalent tonnage 116,000,000) without failure of the rail. Two tests with a 63,000-lb. load cracked the rail and broke down the surface so that the drive belt slipped and the machine would no longer run.

Two tests on the 7-in. stroke machine, 33-in. wheel and 50,000 lb. load, were discontinued at approximately 1,000,000 cycles when pieces of the rail head cracked out.

Specimens which did not fail showed increases of Brinell hardness on the tread ranging from 10 to 26 points (see Table 4), the greatest increase being for the higher loads.

The first indication of impending failure is a crack on the side of the head at the fillet. With subsequent cycles this crack spreads along the fillet and progresses inward until it meets a crack which started on or near the opposite side of the head. A slab of metal soon breaks loose and the rail is considered to have failed. If no cracks develop after 2,000,000 cycles, the test is terminated. A lip has always formed along the edge of the tread.

The stiffness of the loading spring indicating the change of load over the length of the wheel path may affect the cycles for failure. Also it is probable that the contour of the "mutilated" rail head, the height of the reduced tread, fillet radius and degree of surface finish would change the comparative load at which each size of wheel would "break down" the rail.

This type of test specimen is used in the Investigation of Shelly Spots in Railroad Rails by Professor R. E. Cramer, AREA Proceedings, Vol. 44, 1944, page 601; Vol. 45, 1944, page 462.

In Fig. 9 are shown the data for a hardness survey on rail 803D; a cross-sectional sketch of the "mutilated" rail head is also shown. The tread, sides and radii of the head section are ground. (Norton cup wheel 3846–K5 BE).

After testing for 2,000,000 cycles, an increase of hardness of 3 points Rockwell C was measured on the tread at the center line of the head and there is evidence of an increase of hardness as far down as 0.4 in. from the tread. Readings taken ⅛ in. from the edge of the section indicate a higher hardness than at the center line at a depth of 0.025 in., then a gradual decrease until the original hardness is reached at a depth of 0.3 in.

Fig. 10 shows the variation of hardness across the tread at midstroke on specimen 803D. The path width has increased from 1.00 in. to 1.07 in. A maximum reading of Rc 28 was obtained at the center, decreasing to Rc 23 near the bulged edges.

Before testing, the tread was flat across the width within 0.001 in. After the test the tread was found to be 0.009 in. low near the edge with the larger lip, and 0.002 in. low at the opposite edge. Readings 1/16 in. from the edges gave a Rockwell hardness of Rc 23 which is very near the tread hardness as recorded for the untested rail. The readings of Rc 28 at the center of the path indicate a certain amount of work hardening in this region. It is possible that the edges bulged laterally due to heavy pressure near the center of the wheel path. If the surface near the edges bulged by overloading near the edges, it appears probable that the material in this region would show an increase of hardness due to cold work.

The depth hardness survey curve for rail 803A rolled with a 53,000-lb. load is shown in Fig. 11. This specimen was cut from a rail adjacent to specimen 803D. The increase in path width after the test was 0.013 in.; the surface was found to be 0.002 in. low near one edge and 0.004 in. low near the other edge.

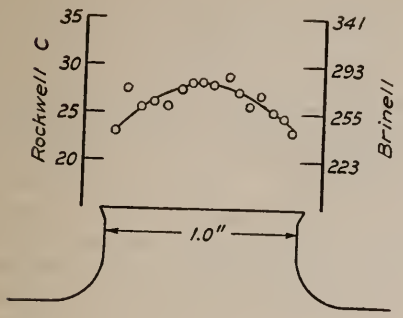


Fig. 10.—Hardness Readings Across Tread of Rail 803D at Midstroke.

Rail No. 803A 131-lb. Wheel load 53,000-lb.
Cycles 2,000,000 Tons 106,000,000
Test surface beveled 1-2.9 Wheel diameter 50-in.
Wheel path 1.0-in. wide

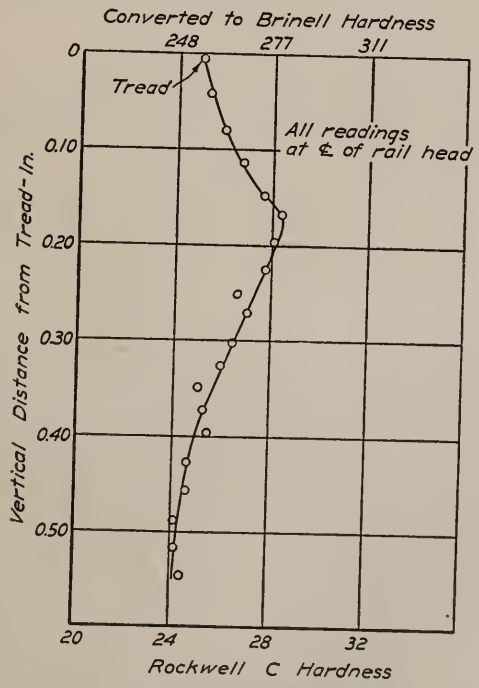


Fig. 11.—Depth-Hardness Survey on Rail 803A with "Mutilated" Head.

Tread hardness at the center of the path was Rc 25 after the test, an increase of less than one point; however, the maximum hardness was found to be Rc 28.5 at a depth of 0.175 in. The specimen showed effects of work hardening as deep as 0.4 in.

Summary of Tests

1. A depth hardness survey on a 112-lb. rail removed from service after approximately 12,000,000 tons of traffic shows the maximum hardness to be at a depth of approximately 0.04 in. at a distance of 1-3/16 in. from the center of the head toward the gage side, the maximum hardness being Rockwell C 34.6.

2. Tests on a full section 131-lb. rail under a 75,000-lb. load after 1,333,000 cycles (100,000,000 tons) of testing are as follows: For the 33 in. wheel—a hardness of Rc 15 on the tread and a maximum of Rc 32 at a depth of 0.15 in.; for the 50 in. wheel—a hardness on the tread of Rc 23 and a maximum hardness of Rc 27.4 at a depth of 0.10 in.

3. For the 60,000 lb. load tests and 100,000,000 tons the results were: For the 33 in. wheel a tread hardness of Rc 21.6 with a maximum of Rc 30.5 at a depth of 0.12 in.; for the 50 in. wheel a tread reading of Rc 15 with a maximum reading of Rc 25 at a depth of approximately 0.13 in. The web of this rail was piped with attendant segregation in the head.

4. The test under the same tonnage with a 45,000 lb. load indicated: For the 33-in. wheel a tread hardness of Rc 19 with a maximum of Rc 32 at a depth of approximately 0.13 in.; for the 50 in. wheel a tread hardness of Rc 25 with a maximum of Rc 31.5 at a depth of 0.10 in.

5. Using "mutilated" head specimens and a 50-in. wheel it was found that a 58,000-lb. load could be carried for 100,000,000 tons, but that a 63,000-lb. load would break down the rail tread after 15–45 million tons. The limiting load was not established for the 33-in. wheel except that a wheel load of 50,000 lb. produced failure in approximately 1,000,000 cycles (55,000,000 tons) in duplicate tests.

6. Hardness surveys on the above type of specimens (50-in. wheel—58,000 lb. load) show an increase of hardness as deep as 0.40 in.

7. On the "mutilated" head specimens the maximum hardness was recorded at the center of the tread.

Future Tests

The series of tests with the full rail section is being repeated with each wheel at loads of 75,000, 60,000, 45,000 and 30,000 lb., specimens being cut from a first quality 39-ft., 131-lb., C rail. The four tests with the 33-in. wheel are completed.

A series of tests is being considered with "mutilated" head specimens to find the limiting break down load for 2,000,000 cycles of testing for both wheel sizes.

Experiments are being made using ¼-in. gage length DeForest–Southwark SR–4 wire resistance gages mounted on the side of the head of a "mutilated" rail, to ascertain the correlation between the shearing stresses as measured on the side of the head with the calculated shearing stresses in the rail head. Tests are being made with various wheel loads.

The Depth Hardness Gradient

The initial loading of a rail by a wheel breaks the mill scale on the tread revealing a rough pitted surface which becomes pebbled and later smooth. Vertical "wear" measurements of the order of 0.01 in. and a rapid widening of the wheel path as the radius of the tread is increased indicate a plastic flow of the decarburized surface.

With subsequent cycles of testing vertical wear continues but at a decreased rate as the rail is overstressed in regions progressively farther from the surface. Maximum compressive surface stresses, 75,000-lb. load and a 33-in. wheel, have been calculated to be as high as 212,000 psi. by the Thomas–Hoersch formulas, Table 5. Calculated maximum shearing stresses are also given as well as the depth at which they occur. Shearing stresses increase from zero at the surface to a maximum at a depth of approximately 0.2 in. from the tread. Since these formulas are necessarily based on elastic action it is considered that the shearing stresses are lessened in the regions of plastic action due to reduced curvatures of the surfaces and readjustments due to non-elastic action.

TABLE 5.—MAXIMUM SURFACE STRESSES IN COMPRESSION

Assumption: Worn rail 24-in. radius of head

$P = 1/4 \quad E = 30{,}000{,}000$

Wheel Load lb.	*Wheel Diameter* 50 in.	33 in.
	lb. per sq. in.	
75,000	180,000	212,000
60,000	165,000	198,000
45,000	150,000	180,000
30,000	135,000	158,000

MAXIMUM SHEARING STRESSES AND DEPTH BELOW SURFACE AT WHICH THEY OCCUR

Wheel Load lb.	*Wheel Diameter* 50 in. Stress psi.	50 in. Depth in.	33 in. Stress psi.	33 in. Depth in.
75,000	58,000	0.206	68,500	0.192
60,000	53,500	0.193	63,500	0.177
45,000	48,500	0.175	57,500	0.161
30,000	42,500	0.153	50,000	0.141

Circular No. D.V. 985, AAR, Operations and Maintenance Dept., Mechanical Division, May 27, 1940 (Read at 1940 meeting, Report of Committee on Wheels).

High compressive stresses at the surface in excess of the original compressive elastic strength cause plastic action resulting in an increased elastic strength and increased hardness. The elastic strength in the region of the surface may be increased sufficiently to allow wheel loads to be carried, that is, this material may act elastically.

Under increasing pressures of wheel on rail the yield strength may be reached in regions progressively farther from the surface of contact. As this material is supported by surrounding material the stresses are partly hydrostatic (three dimensional) and partly shearing in nature, and permanent deformation takes place only after the shearing yield strength has been passed.

Hardness readings indicate that the material has been cold worked and stressed to such an extent that the ductility has been greatly decreased. The hardness given to a material by cold work is considered to be a function of the compressive and shearing yielding. Furthermore, the maximum hardness is not at the surface but at a distance from the surface, being deeper for the higher wheel loadings.

Any segregation or internal discontinuities in the rail in the region which has an increased elastic strength and low ductility may serve as stress raisers and cause such

highly localized stresses at the defects as to cause incipient cracks. Cracks once formed, continue to grow under repeated loading. Eventually a work-hardened slab embracing the surface may break loose resulting in a rail failure.

Significance of Calculated Stresses

(Bulletin 212, University of Illinois, H. R. Thomas and V. A. Hoersch)

An important question which cannot be settled at this time is whether a repeated shearing stress having a maximum in the interior of a body will cause a crack to form and spread under this condition as readily as in the case of a torsion test specimen where the maximum stress is at the surface.

Some preliminary results seem to indicate that cracking and rupture may not start in the interior of a body when the computed shearing stress is somewhat higher than the torsional endurance limit determined in the ordinary way. This needs further study since it is difficult to make tests of this nature without having a change occur in the curvature of the specimen due to wear and hence a quite appreciable change in calculated stresses.

Another question is the possibility of work hardening due to overstress, thus causing a change in physical properties. Residual internal stresses due to cold work and rolling action may have an effect both on the amount of shearing stress produced at the point of contact and possibly on the endurance properties of the material. In fact it would seem that under some circumstances residual internal compressive stresses due to cold work might so affect the shearing stress as to cause the maximum shearing stress to be at right angles to the direction which it could be expected to assume without taking account of the stress due to cold work.

Hardness Testing

It has been pointed out that the indentation test is a relative test as the stresses caused by the indentation are unknown. With the Rockwell cone (Brale diamond penetrator, C scale, 150 kg. load) the hardness reading does not vary with load since the degree of indentation hardening remains constant. The measurement is made on the recovered impression, hence the resulting hardness number is based partly on the flow properties of the material, a measure of its work hardening capacity, and the yield strength. Although, the Rockwell tester measures depth of penetration, a minor load of 10 kg. is applied after which the dial is set to zero. This preliminary load serves to set the indenter firmly by penetrating the test surface, thus minimizing the effect of surface finish.

It has also been noted that internal stresses produced by severe quenching cannot be detected by the indentation hardness test. The presence of a decarburized surface is not too readily detected by hardness tests on the surface. Results of tests on decarburized surfaces vary with depth of indentation; the shallower the depth, the nearer the test comes to being a test of the surface.

The favorable compressive stress developed by shot blasting is not readily detected by a hardness test on the surface, the surface hardened layer being of the order of 0.006 in.

Depth of impressions with the Rockwell C test as given by Scott and Gray Trans., American Society of Metals, Vol. 28, No. 2 are as follows:

Rockwell C hardness	*Depth of impression in.*
62	0.00324
52	0.00409
40.5	0.00507
29.5	0.00601
15.5	0.00721

A conservative minimum thickness of metal that can be accurately tested is 10 times the depth of impression. If the indent shows through on the bottom face, the specimen is too thin and readings may be incorrect due to "anvil effect".

MEMOIRS

MEMOIR

Frank Lorn Campbell Bond, D. S. O.

Died December 9, 1945

Frank Lorn Campbell Bond, a past-president of this Association, a member of the Board of Direction at the time of his death, and one of Canada's outstanding railwaymen for many years, died suddenly in Montreal, Que., on December 9, 1945.

Born in Montreal on February 21, 1877, son of the late Lieut. Col. Frank and Mary Stuart (Scott) Bond, he was educated in Montreal schools and graduated from McGill University with the degree of B.Sc. in 1898. Rachel Mary Dawes, daughter of the late Andrew J. Dawes of Lachine, Que., whom he married in 1908, died December 25, 1945. He is survived by a daughter, Mrs. Robert Thornton.

Frank Lorn Campbell Bond

Mr. Bond, while still a student at McGill University, commenced his railway career in 1897 with the engineering department of the Canadian Pacific Railway on the construction of the short line to Ottawa. Upon graduation from McGill he joined the Grand Trunk Railway engineering staff in 1898 as assistant engineer, worked as engineer on the construction of the New York subway system in 1902, rejoined the Grand Trunk Railway as resident engineer in 1903 and thereafter worked in various capacities until he was made division engineer of Grand Trunk eastern lines in 1913. He was in charge of some of the most important work in connection with the double tracking of the Grand Trunk Railway between Montreal and Toronto.

In 1917 Mr. Bond was granted a commission, with the rank of major, for the purpose of recruiting "C" Company, 256th Railway Construction Battalion, Canadian Expeditionary Force. This battalion proceeded overseas in March 1917 with Major Bond

in charge of "C" Company. He embarked for France with the 10th Canadian Railway Troops in June 1917 and saw service in various parts of Belgium and France. In October 1917 the battalion was transferred to the Ypres salient, in connection with preparation for the offensive at Passchendaele. Major Bond was awarded the Distinguished Service Order and twice mentioned in despatches for devotion to duty and his excellent work in the Ypres salient.

After the Armistice he was recalled to Canada at the request of the Grand Trunk Railway, and was appointed chief engineer of that company on December 15, 1918, which position he held until the formation of the Canadian National Railways in 1923. During his tenure of office as chief engineer of the Grand Trunk Railway he was directly responsible for the preparation of the physical valuation which was submitted to the arbitrators appointed to determine the value of that property.

Early in 1924 Mr. Bond was appointed general superintendent, Montreal district, Canadian National Railways, which position he held until appointed general manager, Central Region, Canadian National Railways, at Toronto, on June 8, 1936. On January 1, 1939, he was appointed vice-president and general manager of the same territory and remained in that position until superannuated February 21, 1944.

Mr. Bond joined the American Railway Engineering Association in 1915 and was deeply interested in its activities. The esteem in which he was held by the membership is indicated by his election as a director in 1936, his election as a vice-presdent in 1939, and his election as president in 1941. At the time of his death he was, as one of the five latest living past-presidents, still a member of the Board of Direction. During his more than nine years as a continuous member of the Board of Direction he endeared himself greatly to all members of that board who served with him. His wise counsel and splendid judgment were an influence which will be felt for many years.

Mr. Bond was an Anglican and a lifelong member of St. George's Church, Montreal, in which he was keenly interested. He was a member of the Engineering Institute of Canada, the Canadian Standards Association, the Corporation of Professional Engineers of Quebec, and the Corporation of Professional Engineers of Ontario, and of the Royal Montreal Golf Club, the York Downs Golf Club, Toronto, the St. James' Club, Montreal, and the Forest & Stream Club, Dorval, Que.

His interest in the welfare of veterans of the first Great War was persistent. While in Toronto he was honorary president of the Canadian National Railways War Veterans' Association, Toronto branch. He was also very keenly interested in the personnel of the railway and ever alert to see that his men received justice and fair treatment.

After his retirement in 1944 Mr. Bond made his home on a farm he had purchased in the vicinity of Lachute, Que. At the time of his death he was in Montreal because of the serious illness of his wife.

Mr. Bond was intensely interested in the success of the railway with which he was identified. This, together with many lovable traits, earned for him not only the respect but the warm friendship of all who knew him well.

Frank Lorn Campbell will be missed by the American Railway Engineering Association and by a host of friends.

J. E. Armstrong, *Chairman*,
H. R. Clarke
E. M. Hastings
F. E. Morrow
J. F. Pringle
Committee on Memoir.

MEMOIR

Burr Robert Kulp

Died February 27, 1946

Burr Robert Kulp, chief engineer of the Chicago & North Western Railway System and an eminent engineer in the railway field, was born in Duncannon, Pa., on December 16, 1883, the son of John David and Alice May (Bowers) Kulp, and died in Evanston, Ill., on February 27, 1946. Following graduation from the high school at Harrisburg, Pa., he entered Rensselaer Polytechnic Institute at Troy, N. Y., from which he received the degree of Civil Engineer in 1905.

Burr Robert Kulp

His entire professional career was spent in the service of the Chicago & North Western Railway, with which company he became identified in July 1905 as instrumentman. His outstanding ability was soon recognized and in 1909 he was promoted to assistant engineer, handling heavy construction projects, until 1913 when he was again promoted to the position of division engineer with headquarters at Antigo, Wis. In 1917 to broaden his experience in transportation he was appointed trainmaster in the operating department, returning to the position of division engineer at Madison, Wis., in 1920, where he remained until 1931, when he was made principal assistant engineer in the office of the chief engineer. In 1936 he was advanced to engineer of maintenance, and in 1940 to chief engineer of the Chicago & North Western Railway. In 1943 his duties were further extended by appointment as chief engineer of the Chicago, St. Paul, Minneapolis & Omaha Railway.

He became a member of the American Railway Engineering Association in 1920 and was elected a member of the Board of Direction in 1941. He served as a member of

the Committee on Rules and Organization, the Committee on Rail, and the Committee on Cooperative Relations with Universities, and was deeply interested in the activities of the Association.

His interests were many and varied. In the professional field his memberships also included the American Society of Civil Engineers, the American Railway Bridge and Building Association and the Maintenance of Way Club of Chicago. He was a member and former director of the Western Society of Engineers and the Western Railway Club. He was a former trustee of Rensselaer Polytechnic Institute, his Alma Mater. Also, he was a member of the Union League Club of Chicago, the Evanston Golf Club, the Masonic Order and St. Luke's Episcopal Church of Evanston.

His professional ability contributed greatly to the success of the railway with which he was identified and this, together with his winning personality, earned him the respect and warm friendship of his associates. His excellent judgment and wise counsel will be long remembered.

In 1907 he married Edna Mary Herbst of Chicago, who died in 1927. Subsequently, in 1929 he married Gertrude Elizabeth Madden of Sparta, Wis., who survives him, together with his son, John Herman Kulp of Detroit, Mich.

In the untimely death of Burr Robert Kulp this Association and the engineering profession lost an outstanding and loyal leader.

H. R. Clarke, *Chairman,*
C. B. Bronson
E. C. Vandenburgh
Committee on Memoir.

MEMOIR

John Boudinot Hunley

Died March 2, 1946

John B. Hunley, past director of the American Railway Engineering Association and a well known railroad engineer, was born at Terre Haute, Ind., August 12, 1881, the son of John Boudinot and Mary (Van Slyke) Hunley. After completing high school at Terre Haute he entered Rose Polytechnic Institute in that city and was graduated in 1903 with the degree of Bachelor of Science in Civil Engineering. He was married to Margaret Gray on June 6, 1909. Mrs. Hunley, a daughter, Mrs. Andrew Chase (Jane Gray Hunley), and a son, John Boudinot Hunley, Jr., survive.

Mr. Hunley began his railroad engineering career with the Cleveland, Cincinnati, Chicago & St. Louis Railway in 1903 and continued with that company until 1940. Between 1903 and 1907 he served as draftsman, designer, engineer on location, and as chief draftsman in the chief engineer's office at Cincinnati.

John Boudinot Hunley

He was placed in charge of the company's track elevation work in Indianapolis in July 1907 and continued in that position until its completion in January 1909. After that work he held the position of assistant engineer for six years in the chief engineer's office. Mr. Hunley was promoted to engineer of bridges and structures in May 1915, and continued in that position, with headquarters at Cincinnati, until May of 1940.

Among the structures for which he was responsible was the bridge over the Miami river at Sidney, Ohio, a two-track, open-spandrel, and semicircular concrete arch structure of three 140 and two 100-ft. spans. It was built in 1923 and was the first large structure in which accurately controlled concrete mixtures were used.

He was also in charge of the design for the renewal of the Louisville and Jefferson bridge over the Ohio river between Louisville, Ky., and Jeffersonville, Ind. This was a single-track, through-truss bridge of six spans from 547 to 200 ft. in length, over the river, with 1¼ miles of deck girder and steel tower viaduct approaches. The distinctive feature of this construction was that the new trusses were erected inside the old, the old spans being used as falsework. This outstanding structure was completed in 1928.

Mr. Hunley was promoted to engineer of structures, New York Central System (West of Buffalo) in May 1940, serving in that capacity, with headquarters in Chicago, until June 1945. During this period he was in charge of a large project involving the renewal, under traffic, of three double-track bridges across Sandusky bay at Bay Bridge, Ohio. These bridges aggregated 1555 ft. in length and included a lift span. The spans were supported on steel cylinders filled with concrete, and were landed into rock about five feet. This work required the most thorough planning and was accomplished in one construction season while approximately ninety trains per day were being handled over the structures.

Mr. Hunley was appointed consulting engineer, New York Central Lines (West of Buffalo) in June 1945, and served in this capacity until his retirement in December of the same year.

He became a member of the American Railway Engineering Association in 1919 and was active in its work until his retirement. He was a member of Committee 14—Yards and Terminals, from 1921–26; and a member of Committee 15—Iron and Steel Structures from 1925 until his death, serving as vice-chairman from 1938 to 1939. He was also a member of the Committee on Live Load and Impact; chairman of the Committee on Impact from 1938 to 1943, and thereafter member of that committee until his death. He was a recognized authority on impact on railroad bridges. He served as member of the Committee on Clearances from 1944 to 1945. He willingly contributed much toward making the AREA the outstanding influence it is today in the railroad industry.

Mr. Hunley served as director of the AREA from 1936 to 1939.

He was an authority on reinforced concrete construction, being the author of a text book on that subject which is used in various engineering schools. Interested in history and writing, he was a former governor of the Society of Colonial Wars, and was a member of the Literary Club in Cincinnati. He was co-author of a privately published book and map on Daniel Boone and the Wilderness Trail. He held membership in the Western Society of Engineers. He received the degree of Doctor of Engineering from Rose Polytechnic Institute.

Devotion to his family, zeal for good citizenship, loyalty to his fellow workers, love of nature, and unselfish effort in the furtherance of the science of railroad engineering provide a lasting monument to the memory of John B. Hunley.

R. A. Van Ness, *Chairman,*
F. R. Layng
G. E. Robinson
Committee on Memoir.

MEMOIR

Gustave Anton Haggander

Died April 14, 1946

Gustave Anton Haggander, assistant chief engineer, Burlington Lines, was born in Sioux City, Iowa, on January 30, 1885, the son of John and Anna Amanda (Segerstrom) Haggander, and died in LaGrange, Ill., on April 14, 1946. Following graduation from high school, he entered Armour Institute of Technology at Chicago, from which he received the degree of Bachelor of Science in Civil Engineering in 1907.

Gustave Anton Haggander

His entire professional career was spent in the service of the Chicago, Burlington & Quincy Railroad, with which company he started work in 1904 as a tracer in the bridge department. His ability was soon recognized and he was advanced in turn to the positions of detailer, inspector, designer, office engineer, and assistant bridge engineer, and on July 1, 1916, he was made bridge engineer, which position he held until he was promoted to assistant chief engineer, Lines East, on May 16, 1939. On February 1, 1943, he became assistant chief engineer for the Burlington Lines.

Mr. Haggander became a member of the American Railway Engineering Association in 1915 and took an active part in committee work. He was a member of the Committee on Wood Bridges and Trestles from 1917 to 1920, the Committee on Complete Roadway and Track Structures from 1934 to 1935 and served as vice-chairman of the Committee on Waterproofing from 1932 to 1935. However, his outstanding contribution to the Association was made during his participation in the work of the Committee on Iron

and Steel Structures with which he was identified from 1917 until his death. He served with distinction as the vice-chairman of the committee from 1928 to 1934 and as chairman from 1934 to 1937. He was elected a director of the Association in March 1945.

He was a corporate member of the American Wood-Preservers' Association and served on its Committee on Bridge and Structural Timbers. He was a member of the Western Society of Engineers, the Western Railway Club, the Chicago Engineers' Club, and the Masonic Order.

Through his professional attainments in bridge design and construction and general railroad engineering he contributed greatly to the success of the railroad with which he was identified and this, together with his sound judgment, administrative ability and fine character, earned him the respect and friendship of all his associates.

In 1915 he married Eva Jane Wright of Chicago who, together with a daughter, Jane Ann (Mrs. Howard Gilkes), survive him.

In the death of Gustave Anton Haggander, this Association and the engineering profession suffered a great loss.

J. E. Bernhardt, *Chairman,*
H. A. Aalberg
R. A. Van Ness
Committee on Memoir.

MEMOIR

Frank Gilbert Jonah

Died December 7, 1945

Frank Gilbert Jonah, son of David A. and Elizabeth Ann (Lutz) Jonah, was born at Lower Coverdale, New Brunswick, October 6, 1864.

The New Brunswick Jonah family is of French speaking Swiss descent, Peter Jonah (originally written Joney) having emigrated in 1765.

The Lutz family, of Dutch origin, originally settled in Pennsylvania and then moved to New Brunswick. Elizabeth was only seventeen when her eldest son, Frank, was born.

Frank's father, David Jonah, was a successful farmer and a well educated man. His lack of much formal schooling was made up for by self study aided by his Scotch mother. David was noted in the neighborhood for his knowledge of the classics and for his ability to recite whole plays from Shakespeare. He was also an ardent fisherman, who taught his son Frank the love of the outdoors. Both parents were physically strong and enjoyed long, vigorous and useful lives.

Frank Gilbert Jonah

Frank's Scotch grandmother saw to it that his inherited fondness for Burns was cultivated. She also taught him of the Scottish clans. It was but natural, therefore, that Frank Gilbert Jonah combined a strong constitution, and a love of nature, with an appreciation of literature and arts, which made him quite outstanding in addition to his ability as an engineer and organizer.

Frank Jonah attended high school at Moncton, N. B., and was graduated with honors. Shortly after graduation he went to work for the Intercolonial Railway in

the engineering department, and finding this work to his liking, he decided to make engineering his profession. He remained with the Intercolonial for five years, or until September 1887, serving as draftsman, chainman, rodman, leveler and transitman on railroad surveys. Between September 1887 and September 1889 he served as resident engineer in charge of construction of the 13-mile Oxford and New Glasgow Railway, at Tatamagouche, Nova Scotia. Returning to the Intercolonial as assistant engineer he remained only until April 1890 when he moved to St. Louis to work under the direction of Robert Moore (Past pres., ASCE) on the St. Louis Merchants Bridge Terminal Railway. Following this engagement Mr. Jonah was appointed resident engineer in charge of construction and maintenance of the St. Louis & Eastern Railway, at Marine, Ill., where he served from April 1894 to May 1897.

While located at Marine, Mr. Jonah met Olivia Richardson, and on March 4, 1896 they were married.

In May 1897, Mr. Jonah was asked to take charge of the location and construction of an extension of the St. Louis, Peoria & Northern (now part of the Alton) from Peoria to Springfield, 57 miles, and moved to springfield, Ill. When this work was completed in December 1899, he became engineer maintenance of way of the Chicago & Alton Railway at Bloomington, Ill. While he was located at Bloomington, the American Railway Engineering and Maintenance of Way Association was organized and Mr. Jonah became a charter member.

In May 1901 he was called to serve as chief engineer in charge of location and construction of the 250-mile Blackwell, Enid & Southwestern Railway at Blackwell, Okla. This property was shortly after acquired by the St. Louis & San Francisco Railway, and thus began Mr. Jonah's long connection with the Frisco properties. In March 1903, he was sent to New Orleans, as assistant engineer for the Frisco, which railroad, at that time, was planning entry into that city. In June of the same year he became chief engineer of the Frisco sponsored St. Louis, Brownsville & Mexico Railway, extending from Houston to Brownsville, Tex. The construction of that line, as a part of what became known as the Gulf Coast Lines, is a story in itself, well told in Allhand's book, "Gringo Builders." Although the country is flat, it presented many formidable obstacles to Jonah's work of building this pioneer railroad. Yellow fever was not the least of these obstacles. To quote from Gringo Builders, "As that was in the day of the livery stable, and before engineering parties had changed from oats to gasoline, their getting about was by hack, wagon, and ambulance, laborious and slow.

"Except for the fastness of the jungle region in proximity to the Rio Grande, the easy nature of the topography rendered the engineering a simple problem, but there the prickly pear (cactus) grew into trees six and eight feet high, and the brush was so dense that it was well nigh impossible to run out the drainage areas. Frequently Colonel Jonah's party would return to camp snagged and scratched up with cactus and cats claw, tired and hot after a strenuous day's struggle through the undergrowth of brush . . ."

"Throughout the early work Colonel Jonah handled all engineering matters, prepared plans and made all surveys. He always chose the most direct and practical route of permanent and economical alinement, without curves or grades, straight as an arrow through undeveloped country.

"This work, from an engineering standpoint, was organized and carried forward with exceptional thoroughness. The men liked to work for this practical engineer and builder and his leaving the line was generally regretted."

In his "History of the Texas Railroads," S. G. Reed says, "It's safe to say that the building of the Gulf Coast Lines in 1904 . . . caused a greater increase in land

values, population and taxable values than any railroad construction in the United States of similar length and in such a short period of time."

After the construction of the Brownsville road was well under way, Mr. Jonah was detached to look out for other critical parts of the extensive Frisco program in the Gulf area. Between May 1905 and December 1909, he spent most of his time at New Orleans where he built the New Orleans Terminal Railroad and the passenger station on Canal Street, both of which were planned for Frisco use, but both of which are now owned by the Southern Railway. When the New Orleans work was completed, Mr. Jonah became chief engineer of construction for the Frisco, with headquarters in St. Louis, and on March 1, 1913 was promoted for to chief engineer.

At this time the Frisco was engaged in transforming its properties from the pioneer type of railway to a more efficient transportation machine. The day of construction of new lines was over. Mr. Jonah was engaged on this program when World War I interrupted.

At the beginning of the war Mr. Jonah took a leading part in organizing the 12th Engineers, a St. Louis regiment. After training, this regiment was sent overseas. Mr. Jonah was commissioned Major. He saw active service on the British front in Picardy from August to November 1917, or until—the American Army organized its own department of Light Railways, of which Major Jonah was made chief engineer. He served under General Jadwin, later Chief of Engineers, U. S. Army. It was under these circumstances that he planned most of the light railways built by the American Army. He was promoted to the rank of Lieutenant Colonel, and was discharged, with honors, in 1919, receiving a Headquarters Citation for Exceptionally Meritorious and Conspicuous Services, and also a special letter of commendation from General Pershing. For the Headquarters Citation he was later awarded the Medal of the Purple Heart. In 1920, the Polish Government awarded Colonel Jonah a diploma and medal.

Immediately upon returning from overseas service, Colonel Jonah resumed his duties as chief engineer of the Frisco Railway and served in that capacity until his death.

In St. Louis, Colonel Jonah was very active in civic affairs. He served on numerous committees, such as those having to do with the Soldiers Memorial Building, the city building code, and on those appointed to deal with the very complicated railroad terminal problems. At the time of his death he was serving on a committee appointed by the Governor of Missouri to report on the advisability of a Missouri Valley Authority, patterned after the T. V. A., and was one of the five of the membership of seven, who reported against such M. V. Authority.

Because of his achievements and his personal popularity, he was prominent in many organizations. He held charter membership in the American Railway Engineering Association and in the Society of American Military Engineers. Of the latter he was president in 1931. In 1917 he was president of the Engineers' Club of St. Louis. He was elected director of the American Society of Civil Engineers in 1916, but resigned the following year on his departure for France. In 1913 he was elected vice-president of the same society and served on important committees of its Board of Direction.

His inherited and cultivated taste for Burns was shown by membership in the Burns Club of St. Louis. Of Shakespeare, he was likewise both fond and an authority. Another interest was the history of transportation, on which he did much research, from the time of primitive man to the perfection of modern transport. As a student of archeology, he lectured on the Pyramids, and loved to explain how the

gigantic 1400 ton blocks of stone could have been placed in position through the use of sand funnels.

By nature Colonel Jonah was most sociable—a jovial host and a convivial companion. He enjoyed a well-earned reputation as a story teller. No one better than he knew and appreciated good food and its concomitants.

He possessed in unusual degree a hard, practical common sense, a keen sense of the economic values underlying most engineering work and an uncanny capacity for emphasizing and giving due weight to the important aspects of every problem. He never ignored the practical aspects of his work. He was a close observer, a sympathetic but firm supervisor, and wholly intolerant of sham or hypocrisy.

As stated above, Colonel Jonah was married in 1896. The union was blessed with three daughters, Mrs. Julia Neely, Mrs. Ruth McClosky and Mrs. Lois LaCroix.

After a happy married life of almost forty years, Mrs. Jonah died on February 3, 1935. In the words of one of his daughters, Frank Jonah was a wonderful father, a devoted grandfather and a proud great grandfather.

Colonel Jonah died at St. Louis on December 7, 1945.

F. W. Green, *Chairman,*
H. B. Barry
W. J. Burton
Committee on Memoir.

American Railway Engineering Association

CONSTITUTION

Revised to October 19, 1943

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meetings for discussion of reports and papers.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions reached shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Illinois.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than twenty-five (25) years of age.

(b) To be eligible for election to or retention of membership as a Member or an Associate, a person shall not be engaged directly and primarily in the sale to railways of appliances, supplies, patents or patented services.

B. MEMBER

A Member shall be:

(a) An Engineer or Officer in the service or on the retired list of a railway corporation who has had not less than five (5) years' of experience in the location, construction, operation or maintenance of railways.

Graduation in engineering from a school of recognized standing shall be considered as equivalent to three (3) years of active practice, and the satisfactory completion of

each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(b) A Professor of Engineering in a university or college of recognized standing.

(c) An Engineer or Member of a public board or commission who in the discharge of his regular duties deals with railway problems.

(d) An Engineering Editor of a magazine which deals primarily with railway matters.

C. Life Member

A Life Member shall be a Member who has paid dues for thirty-five (35) years, or who has been retired under a recognized retirement practice and has paid dues for not less than twenty-five (25) years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten (10).

E. Associate

An Associate shall be:

(a) An Engineer of a railway which is essentially an adjunct of an industry or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to co-operate with Members in the object of this Association but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than twenty-one (21) years of age and shall be an engineering employee of a railway corporation who has had not less than three (3) years of experience in the location, construction, operation or maintenance of railways.

Graduation in engineering from a school of recognized standing shall be considered as equivalent to three (3) years of active practice, and the satisfactory completion of each year of work in such school without graduation, shall be considered as equivalent to one-half year of active practice.

(b) His membership in this Association shall terminate at the end of the calendar year in which he becomes thirty (30) years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members and Life Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members

who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association, except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15th, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the application shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of such Members shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(c) If an applicant is not personally known to three Members of this Association, the names of at least three well known persons engaged in railway or allied professional work to whom personally known shall be given instead. Each of such persons shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with all the information obtained, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible and the admission of the applicant shall be canvassed by letter ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

A person elected to membership in this Association shall subscribe to its Constitution on the form prescribed by the Board of Direction. If this provision has not been complied with within six months of notice of election the election shall be considered null and void.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The

nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fully met.

7. Expulsion

Charges may be preferred in writing by ten or more Members against a person holding membership in the Association. The person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of ten dollars ($10.00) shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be payable to the Association on account of Junior Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be ten dollars ($10.00).

(b) The annual dues for each Junior Member shall be five dollars ($5.00).

(c) Life Members and Honorary Members shall be exempt from the payment of dues.

3. Arrears

A person whose dues are not paid before April 1st of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1st further notice shall be given and a delinquent Member shall lose the right to vote. If the dues remain unpaid October 1st the person shall be notified on the form prescribed by the Board of Direction, and shall no longer receive the publications of the Association. If the dues are not paid by December 31st, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice-Presidents, nine Directors, a Secretary and a Treasurer.

(b) The President, the Vice-Presidents and the Directors, together with the five latest living Past-Presidents continuing to be Members, shall constitute the Board of Direction, in which the government of the Association shall be vested, and shall act as Trustees and have the custody of all property belonging to the Association. The President, the Vice-Presidents and the Directors shall be Members.

(c) The Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice-Presidents two years and of the Directors three years. The term of each shall begin at the close of the Annual Convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position during the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each Annual Convention a President, one Vice-President and three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election. Vice-Presidents and Directors shall not be eligible for re-election to the same office until at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) When a vacancy occurs in the office of President the duties shall be performed by the senior Vice-President.

(b) When a vacancy occurs in the office of either Vice-President the Board of Direction shall select a Vice-President from the members or past members of the Board of Direction. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) A vacancy in the office of Director shall be filled by the Board of Direction.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provisions of Article V, Section 4.

6. Vacation of Office

(a) When an elected officer ceases to be a Member of the Association, as provided in Article II, the office shall be vacated.

(b) In case of the disability of or neglect in the performance of duty by an officer, the Board of Direction, by a two-thirds affirmative vote of the entire Board, shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not officers shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past-President who is a member of the Committee shall be the Chairman of the Committee. In the absence of the senior Past-President from a meeting of the Committee the Past-President next in seniority present shall act as Chairman.

2. Method of Nominating

(a) Prior to December 1st of each year the Chairman shall call a meeting of the Committee at a convenient place, at which nominees for the various elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee.*	*Number of Candidates to be elected at the Annual Election of Officers.*
President	1	1
Vice-President	1	1
Directors	9	3
Nominating Committee	10	5

(b) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

(c) At any time between January 1st and February 1st any ten or more Members may send to the Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each Annual Convention, the Secretary shall issue a ballot to each voting member of record in good standing, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names

shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate, his record of membership and activities in this Association.

4. Substitution of Names

Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw a ballot, and cast another, at any time before the polls close.

(c) Ballots not endorsed or from persons not qualified to vote shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by tellers appointed by the Presiding Officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

(c) The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio a member of all committees, except the Nominating Committee.

2. Vice-Presidents

The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and shall discharge the duties in case of a vacancy in the office.

3. Treasurer

The Treasurer shall receive all monies, deposit the same in the name of the Association, receipt to the Secretary therefor and invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. The Treasurer shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, shall be under the direction of the President and Board of Direction, the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. The Secretary shall see that the monies due the Association are collected and without loss transferred to the custody of the Treasurer, and shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. The Secretary is to conduct the correspondence of the Association, keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The accounts of the Treasurer and of the Secretary shall be audited annually by an approved accountant under the direction of the Finance Committee of the Board of Direction.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

(b) The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the Annual Convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publication
Outline of Work of Committees
Personnel of Committees
Membership
Manual

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of monies and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money

other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision of the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall prepare and present to the Board of Direction a report of the subjects to be investigated, considered and reported upon by the standing and special committees of the Association during the ensuing year.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall prepare and present to the Board of Direction a list of chairmen, vice-chairmen and members of the standing and special committees of the Association for the ensuing year.

(e) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(f) Manual Committee

The Manual Committee shall study and recommend to the Board of Direction as to the manner in which the material adopted for addition or deletion from the Manual shall be handled.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Illinois. The convention shall open on a Tuesday in the month of March to be determined by the President.

(b) The Secretary shall notify all members of the Association of the time and place of the Annual Convention at least thirty (30) days in advance thereof.

(c) The order of business at the Annual Convention of the Association shall be:

Reading of the Minutes of the last meeting
Address of the President
Reports of the Secretary and the Treasurer
Reports of Committees
Unfinished Business
New Business
Installation of Officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to members and to those others invited by the Presiding Officer to speak.

2. Special Meetings

Special meetings of the Association may be called by the Board of Direction and special meetings shall be so called by the Board of Direction upon written request of thirty Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten (10) days in advance and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five (25) Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed Amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members and shall be acted upon in the following manner:

The amendment shall be presented to the Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes the matter shall be submitted to the Association by letter-ballot.

The Board of Direction shall canvass the ballots which have been received within sixty days after the date of issue of the letter-ballot and if two-thirds (⅔) of the votes so received are in the affirmative the amendment shall be declared adopted and shall become immediately effective.

The result shall be announced at the next Annual Convention.

GENERAL INFORMATION

(Revised to March 1946)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS

(A) Appointment of Committees and Outline of Work

Standing Committees

1. The following are Standing Committees:

1. Roadway and Ballast.
3. Ties.
4. Rail.
5. Track.
6. Buildings.
7. Wood Bridges and Trestles.
8. Masonry.
9. Highways.
11. Records and Accounts.
13. Water Service and Sanitation.
14. Yards and Terminals.
15. Iron and Steel Structures.
16. Economics of Railway Location and Operation.
17. Wood Preservation.
20. Uniform General Contract Forms.
22. Economics of Railway Labor.
24. Cooperative Relations with Universities.
25. Waterways and Harbors.
27. Maintenance of Way Work Equipment.
28. Clearances.
29. Waterproofing.
30. Impact and Bridge Stresses.

Special Committees

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Section 9, of the Constitution.

Personnel of Committees

3. The personnel of all committees shall be revised annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committees during the year or render no service by correspondence will be replaced. The terms of chairmen and vice-chairmen shall be three years in each position.

Outline of Work

4. As soon as practicable after the reports of committees for the current year have been filed with the secretary, the Board of Direction will assign to the committees, subjects which in its judgment should preferably be considered during the succeeding year, provided, however, that such assignments may be subject to revision until the close of the Annual Convention. *Such assignments should not be deviated from except in extreme cases and then not until approved by the Committee on Outline of Work.*

(B) Preparation of Committee Reports

General

5. The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information," and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

(a) Whether the report on any particular assignment should take the form of "information" or a "recommended practice," depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant their presentation as information prior to the submission of the recommendations. In some cases, also, it may be advisable to submit as information matter in the form of recommended practice, with a view to inviting suggestions and criticisms that may serve as the basis for revisions prior to the resubmission of the matter for adoption a year later.

Planning the Work

6. In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

(a) Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

(b) Requests for appropriations for the conduct of research work should be sent to the secretary with a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and, (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigations. A request for funds to continue or complete an investigation shall include a statement of the results obtained to date.

Reports

7. Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on those assignments regarding which pertinent information has been developed.

(a) Committees are privileged to present the results of any special study or investigation they may be engaged upon in connection with their assignments that may be considered of sufficient importance to warrant presentation.

(b) Reports of information, supplementing previous reports of progress, may include a brief review of matter previously presented, but should avoid extended repetition of such matter.

(c) Matter offered for adoption and publication in the Manual should be submitted in full, regardless of its publication in previous years unless the matter being offered appeared in substantially identical form not more than one year before being submitted for adoption.

(d) Illustrations accompanying reports should, when possible, be prepared so that they can be reproduced on one page. The use of inserts should be avoided.

(e) One of the most important duties of each committee is to examine its own subject matter in the Manual each year and submit such revisions of or supplements to the Manual as are deemed necessary to keep it up to date. New matter for publication in the Manual and revisions thereof must be submitted in the form and manner specified in the General Rules for Publication of the Manual.

Form of Reports

8. Committee reports shall be prepared in accordance with the Style Standards for Committee Reports appearing on following pages.

(C) Publication of Reports

Dates for Filing and Publication of Reports

9. For the convenience of those attending the convention, the reports of committees to be presented at any session of the annual convention will be published, so far as possible, in the same bulletin. To carry out this plan requires a careful scheduling of the filing of reports and the publication of bulletins, and the arrangement of the convention program. It is of utmost importance that chairmen file complete reports of their committees on or before the dates specified on the schedule furnished them.

Written Discussions

10. Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

Verbal Discussions

11. When necessary to insure accuracy, the speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) Consideration of Committee Reports

Sequence

12. The sequence in which committee reports will be considered by the convention will be determined by the Board of Direction.

Method

13. Reports offered as information will be presented by title or by a brief outline of the contents. Comments or criticisms may be offered from the floor upon invitation from the presiding officer.

14. Matter submitted for adoption and publication in the Manual may receive consideration by one of the following procedures:

(a) Reading by title.
(b) Reading, discussing and acting upon each conclusion separately.
(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Action on Reports

15. No formal action is to be taken by the convention on matter submitted as information, whether in the form of a progress or final report.

Action on matter submitted for adoption and publication in the Manual will be one of the following:

(a) Adoption as a whole as presented.
(b) Affirmative action on the amendment of a part or parts of the matter presented, followed by adoption as a whole, as amended.
(c) Adoption of a part, complete in itself, and referring of remainder back to the committee.
(d) Recommittal with or without instructions.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

(E) Publication of Abstracts by Technical Journals

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or committees presenting such material.

GENERAL RULES FOR PUBLICATION OF THE MANUAL

Title

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall have the authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Contents

3. The matter adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material, device, plan, specification or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Requisites for Adoption

4. The Manual will include only such matter as has been made the subject of a special study by a standing or special committee and embodied in a committee report. published not less than thirty days prior to the Annual Convention, and submitted by the committee to the Annual Convention, and which, after due consideration and dis-

cussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction shall be reviewed by the Association of American Railroads, may be referred to that association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the committee report and subsequent discussion and the final action of the Association.

Revision

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent Annual Convention, provided such changes are proposed in time for publication not less than thirty days prior to the Annual Convention, and in the following manner: (a) upon recommendation of the committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those that have been withdrawn by action of the Association.

REPORT OF THE SECRETARY

March 1, 1946.

To the Members:

For the second time in the history of the Association, the report of the secretary covers a year in which no annual meeting was held. However, the pattern of the report is the same, in that the statement on finance covers the calendar year, the figures on membership embrace the period from February 15, 1945 to February 15, 1946, and all other activities cover the 12 months ending with the annual meeting.

To sum up the conventional record as presented in detail on following pages: The accounts of the Association show that both the revenues and expenses increased during 1945 and that there was a "net" of $2,936.33; there was an increase of 103 in the membership, bringing the total to 2,107; and the committees submitted a total of 546 pages of reports, compared with 756 pages in the previous year, a reflection of the limitations on committee work imposed by war and post-war conditions. Committee work continues to evidence the influence of the research work being carried on with funds provided by the Association of American Railroads, both in the character of the reports and in the extent to which the text matter represents the work of research men.

The sustained demand for the publications, especially the Manual, is manifested in increased revenues from this source and has led to the depletion of the stock of Manuals, while circumstances have precluded the completion of the reprinting program until late in 1946. In the meantime the prospect of still further increase in the size of the Manual was responsible for a change to a two-volume arrangement when it became necessary to buy new binders during 1945. This change carried with it an increase in the price to members from $5 to $7.

Membership

The membership record for the period February 15, 1945, to February 15, 1946, was as follows:

Members on rolls as of February 15, 1945		2,004
New members		160
Reinstatements		22
		2,186
Lost by death	36	
Resigned	26	
Dropped	12	
Transferred from Junior to Full Member	5	79
		2,107
Net gain	103	
Membership as of February 15, 1946		2,107

The composition of the membership as of February 15, 1946, compared with that on corresponding dates in the four previous years was as follows:

	1942	*1943*	*1944*	*1945*	*1946*
Life	168	182	182	197	246
Member	1,466	1,496	1,485	1,515	1,564
Associate	272	249	257	259	262
Junior	37	38	38	33	35
	1,943	1,965	1,962	2,004	2,107

Examination of this table conveys the impression of a trend toward a marked increase in the membership, since it shows that 160 new members were admitted in the year ending with February 15, 1946, compared with 128 for the previous 12 months. However, it is necessary to bear in mind that of the 160 new members, 31 are Chinese railway engineers now in the United States as a result of the "trainee" program. Thus, it is evident that a considerable portion of the increase in membership is the result of a distinctly special condition which cannot be expected to continue.

During the 12 months ending with February 15, 1946, losses suffered by the Association due to the death of its members amounted to 36. Among these was F. L. C. Bond, past-president, and a member of the Board at the time of his death. Also recorded among the deceased were W. D. Williams and F. G. Jonah, two charter members, and L. G. Curtis, G. M. Davidson, A. F. Maischaider, P. B. Motley and J. A. Peabody, members who will be remembered for their valued work on the committees in earlier days. Also warranting special mention are O. F. Dalstrom and H. M. Stout, whose helpful service on the committees extended into recent years.

Finances

The financial statement for the calendar year of 1945, which appears on a following page, may be summarized as follows:

Receipts	$32,305.63
Disbursements	29,300.25
	$ 3,005.38
Loss from sale of bonds	69.05
Excess of receipts over disbursements	$ 2,936.33

Compared with 1945, both the receipts and the disbursements were larger, but the excess of the receipts over the disbursements is almost $2000 less than it was in 1944. On the other hand, the "net" differed markedly from the budget forecast, due to an unforeseen circumstance, namely, a pronounced increase in applications for membership and in the sale of Manuals and other publications on account of the Chinese engineers' training program. These produced a double effect—(1) an increase in the receipts in both

Comparison of Receipts and Disbursements for a Ten-Year Period

		Disbursements		
	Receipts	*Normal*	*Manual**	*Track Plans*
1935	$29,001	$25,311	$4,799	
1936	28,643	25,050	9,612	
1937	36,523	23,605	8,595	
1938	28,422	23,394		
1939	28,189	22,969		$ 878
1940	28,272	24,000	665	1,786
1941	32,433	24,972	2,154	2,258
1942	31,500	23,235	2,505	952
1943	28,736	20,309	1,600	1,900
1944	30,492	25,334	1,200	
1945	32,305	25,805	3,500	

* Outlay for loose-leaf Manual, except cost of annual supplements.

the Membership and Publication Sales accounts and (2) an augmented program for the reprinting of the Manual. Originally programmed for 1946, this reprinting was rescheduled for 1945, but for reasons explained elsewhere in the report, it was necessary to return to the original plan for a 1946 edition. However, the 1945 operations were carried far enough to involve some outlay for printing, as well as the purchase of 1000 new binders, entailing expenditures for the Manual in 1945, exclusive of charges for the supplement, of about $3500. As the Manual reprinting in 1946 is imperative, the outlay for that purpose will be very much larger than in 1945.

With every reason to expect a decline in the revenues during 1946, and with the prospects of rising costs and the certainty of extraordinary expenditures for the Manual, it is evident that the Association will be required to absorb some part of the disbursements by withdrawals from its reserves.

Publications

Bulletins and Proceedings

The number of text pages in the seven bulletins ending with Bulletin 458, February 1946, was 781, or 524 less than in the seven bulletins ending with February 1945, but 50 pages more than in the seven bulletins ending with February 1944. The disparity as between the year just ended and the prior year is accounted for in part by the fact that neither of the "summer" bulletins of 1945 were of any appreciable size, whereas the September–October bulletin of 1944 contained the well-known Counterbalance report of 313 pages.

The number of pages in the committee reports totaled 546 or 210 less than in the year ending with March 1945, but 68 pages more than two years ago. In the present year, as was the case a year ago, the preponderance of the committee report material appeared in the last bulletin, as is indicated by the following:

Bulletin 455, November 1945	64	pages
" 456, December 1945	92	"
" 457, January 1946	112	"
" 458, February 1946	230	"

Attention was directed to this disparity in the report of the secretary in 1945, in which reference was made to a proposed regrouping of the committee reports with the object of obtaining a greater uniformity in the size of the bulletins. To this end arrangements were made to include in the last bulletin (February 1945), the reports of only three committees, namely, Roadway and Ballast, Rail and Track. However, even with this change Bulletin 458 contains more than twice the number of pages in any of the others.

In a further effort to increase the distribution of the committee report material, two preliminary reports of the Committee on Track were published in Bulletin 453 for June–July 1945, involving a total of 46 pages. This material, together with the other monographs appearing in that and the following bulletin, afford an excellent diversification of subject matter, as indicated below.

Contents of Bulletin 453, June–July 1945

Preliminary Reports of Committee 5—Track
- Stress Measurements on Various Designs of Solid Manganese Crossing Frogs
- Effect of the Form of Tie Plate Rail Seat on Stresses in Rail Base Flanges and Lower Web Fillets

The Effect of the Ratio of Wheel Diameter to Wheel Load on Extent of Rail Damage—N. J. Alleman

Preliminary Report of Committee 3—Ties

Contents of Bulletin 454, September–October 1945

Determination of Lateral Outward Forces on Each Rail of a Turnout

Two Problems in Bridge Design—L. T. Wyly

Progress Report on Fatigue Strength of Structural Welds

Vol. 46 of the Proceedings (1945) contained 910 pages, 136 more than in Vol. 45.

AREA News

The AREA News, now in its second year, is still receiving favorable comment. When this innovation was authorized by the Board of Direction in the summer of 1944, no specific policy was adopted with respect to the size or scope of this added service to the members. The 12 issues published in 1945 contained a total of 68 pages, or an average of 5.7 pages per issue. Whether the potential service to the membership warrants an expansion of this publication is a matter that would require a careful study of all factors involved, including added publication costs, increase in the staff and other factors.

Manual

Only 44 new sheets were issued in the Manual supplement for 1945, the smallest number since the first supplement to the 1936 loose-leaf Manual was issued in 1937. As the instructions which accompanied this supplement called for the removal of 45 sheets, there was a net reduction of one sheet. Included among the changes embodied in the 1945 supplement was the transfer of the material in Chapter 21—Economics of Railway Operation to Chapter 16 which was given the new name of Economics of Railway Location and Operation. The Chapter on Live Load and Impact embracing but a single sheet was withdrawn and appropriate adjustments made in other chapters At the request of Committee 6—Buildings, and Committee 14—Yards and Terminals, the Board of Direction had granted authority for the withdrawal of Chapter 23—Shops and Locomotive Terminals, with the object of having the material in that chapter distributed between Chapters 6 and 14. However, because the two committees could not complete the task involved in this distribution, it was necessary to carry over this change into 1946.

Record of Manual Supplements

Supplement	*New Sheets Issued*	*Old Sheets Withdrawn*	*Net Increase*
1937	110	69	41
1938	151	121	30
1939	128	95	33
1940	185	139	46
1941	148	120	28
1942	144	149	—5
1943	176	158	18
1944	131	109	22
1945	44	45	—1
Total	1,217	1,005	212

Because of the failure of this and other projects for the completion of desired adjustments and revisions of the Manual prior to its reprinting, and because estimates of the prospective Manual sales during 1945 indicated the possibility of carrying over a small stock into 1946, it was deemed inadvisable to attempt the reprinting of the Manual during the last year. However, the large amount of work still to be done on the Manual to put it in condition for reprinting will tax the efforts of the committees, as well as the Association's staff. Moreover, a recent canvass of the progress made by the committees in reviewing the definitions in the Glossary indicates that the Glossary will have to be omitted from the 1946 printing schedule. It is clearly evident that another year's work will have to be done by the committees on this part of the Manual.

In the meantime there has been a marked increase in the demand for the Manual, originating primarily among the Chinese trainees. As a result the stock of the Manual was completely exhausted at the end of the year so that the sales will be completely suspended until the reprinting has been completed in the fall of 1946.

As the stock of Manual binders was being rapidly depleted during the past year, arrangements were made for the purchase of a thousand new binders involving the adoption of a plan for the issuance of the Manuals in two volumes. This problem was brought to a head in the course of preparation for reprinting the Manual, since circumstances required the use of a somewhat thicker paper than heretofore, thus exhausting at once the limited margin of reserve capacity in binders of the dimensions previously provided. Not a few comments had been received from Manual users during the last year or two regarding the cumbersome proportions of the book, contending that it had become too heavy for ready reference. The greater cost of furnishing a Manual in two binders instead of one, necessitated a change in the price schedule with the result that the price to members is now $7 instead of $5.

Work of the Committees

With the disbanding of the committees on Signals and Interlocking, Electricity, and Standardization a year ago, the number of active committees was reduced to 22, the smallest number since 1920. Since that time the special committees on Waterproofing of Railway Structures and on Impact have been given the status of standing committees and their names have been modified. The former becomes Committee 29—Waterproofing, in the interest of brevity, and the latter is now known as Committee 30—Impact and Bridge Stresses, to indicate more accurately the scope of its responsibilities. The request of the Committee on Water Service, Fire Protection and Sanitation, that the words, "Fire Protection" be deleted from its name was approved in recognition of the fact that the committee no longer has any direct responsibility for studies in this field and because it was desired to avoid any appearance of overlap of the prerogatives of the Fire Protection and Insurance Section, AAR.

While the number of committees has thus been markedly reduced in the last eight years, there has been no corresponding reduction in the number of persons serving on the committees. Thus in 1937, 699 members served in a total of 924 places on 31 committees, whereas in 1945 an average of 680 members occupied 820 places on 22 committees.

Obviously, no appreciable improvement could be expected during 1945 in committee activity. Thirty-two committee meetings were held, compared with 30 in 1944, and only 5 committees held no meetings at all, compared with 10 in 1944. Seven committees held two meetings and four of them held three meetings.

The cumulative effect of wartime conditions is manifested to an even greater extent in the decline in the volume of committee reports, and in the continuation of the trend previously observed whereby the preponderance of the report material is prepared by members of the research staff or the staff of the University of Illinois. Thus, of 546 pages of material encompassed in the committee reports, 217 were prepared by persons employed in research work.

Further analysis of the material in the committee reports is shown in the tabulation in which the reports are classified as to subject matter. No marked change in trend is observed except an appreciable restoration of activity in revision of the Manual, which is indicative of the efforts to bring the material up to date prior to the contemplated reprinting during the summer of 1946.

	1942	*1943*	*1944*	*1945*	*1946*
Revisions of the Manual—minor	6	4	6	6	10
Revisions of the Manual—major	12	4	6		7
New Manual material—minor	2	2		1	
New Manual material—major	11	9	10	2	3
New Manual material—tentative	5	5	2	2	1
Information	37	41	45	33	32
Information—with brief conclusion for Manual	2				
Reports on research work	10	11	12	12	14
Reports on service tests	4	4	2	4	5
Statistical data	6	7	5	3	2
Analytical studies	5	5	2	2	2
Bibliographies	3	2	3	2	2
Brief report of progress	17	5	18	7	7
War emergency provisions and reports		13	4	4	1
	116	112	115	76	86

Research Work

As will be observed in the tabulation of the funds appropriated for research work of the Engineering Division, almost all of the projects listed have either a direct or indirect bearing on the work of the AREA committees. It will be noted also that the total authorization for 1946 is $153,510 or an increase of $15,400 or 11.1 percent more than the amount provided for use in 1945. The growth of these annual allotments for research work is indicated in the table below:

1938	$ 78,158	1943	$ 98,445
1939	77,650	1944	109,050
1940	69,250	1945	138,110
1941	95,150	1946	153,510
1942	87,932		

Inability to obtain access to the necessary equipment and shortage of personnel have militated against the desired progress on some of these projects during the war years, with the result that the funds allotted have not been spent in all cases. However, a large amount of work has been done on most of them as evidenced by the reports presented by the committees on Rail, Track, and Roadway and Ballast. Supplementing the material on the various investigations having to do with tracks and roadbed, a further progress report on work completed to date in the investigation of impact in steel railway bridges will be published in the June–July bulletin for 1946.

ENGINEERING DIVISION ALLOTMENTS FOR RESEARCH

	1944 Budget	*1945 Budget*	*1946 Budget*
Committee on Rail			
Rail failure investigation	$ 6,500	$ 6,938	$ 6,938
Transverse fissure investigation	6,000	6,000	6,000
Service tests of joint bars	2,980	2,980	2,980
Rolling-load tests of joint bars	3,000	5,000	7,000
Investigation of shelly spots and head checks	7,000	7,000	7,000
Investigation of engine burns	1,000	2,000	11,000
Rail design investigation	10,000	15,000	15,000
Total	$ 36,480	$ 44,918	$ 55,918
Committee on Track			
Investigation of stresses in tie plates	$ 4,500	$ 10,500	$ 10,000
Bolt tension tests and rail lubrication	1,500	4,500	4,500
Corrosion from brine drippings	1,000	1,000	1,000
Welding of manganese frogs	1,000	1,000	1,000
Stresses in manganese frogs	5,000	5,000	5,000
Rail anchorage	3,000	3,000	3,000
Total	$ 16,000	$ 25,000	$ 24,500
Relation Between Track and Equipment			
Locomotive counterbalancing tests	$ 5,000	$	$ ....
Rail gage and wheel contour	10,000	10,000	10,000
Relation, wheel load—wheel diameter	5,000	5,000	5,000
Flat spot investigation	5,000	10,000	10,000
Total	$ 25,000	$ 25,000	$ 25,000
Structural Projects			
Impact investigations	$ 15,200	$ 16,000	$ 16,000
Fatigue strength of structural welds	5,000	5,000	5,000
Total	$ 20,200	$ 21,000	$ 21,000
Miscellaneous Projects			
Research office	$ 10,270	$ 11,092	$ 11,092
Electrolysis study	1,000	1,000	1,000
Roadbed stabilization	....	10,000	15,000
Boiler feedwater study	100	100	....
Total	$ 11,370	$ 22,192	$ 27,092
GRAND TOTAL	$109,050	$138,110	$153,510

W. S. LACHER,
Secretary.

Deceased Members

J. P. Anderson
Division Engineer, Nashville, Chattanooga & St. Louis Railway, Atlanta, Ga.

C. R. Beall
Chief Engineer, Union Switch & Signal Company, Pittsburgh, Pa.

G. J. Bell
Retired District Engineer, Atchison, Topeka & Santa Fe Railway, Chicago

F. L. C. Bond
Retired Vice-President and General Manager, Central Region, Canadian National Railways, Lachute, Que.

C. J. Coon
Retired Assistant Engineer, New York Central Railroad, Locke, N. Y.

L. G. Curtis
Retired Chief Engineer, Baltimore & Ohio Chicago Terminal Railroad, Chicago

A. H. Dakin
977 Anderson Avenue, New York, N. Y.

O. F. Dalstrom
Retired Engineer of Bridges, Chicago & North Western Railway, Princeton, Ill.

Arthur Daniels
Division Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Minneapolis, Minn.

G. M. Davidson
Retired Industrial Engineer, Chicago & North Western Railway, Oak Park, Ill.

C. F. Edwards
Division Engineer, Chesapeake & Ohio Railway, Columbus, Ohio

L. E. Elliott
Service Engineer, National Aluminate Corporation, Lexington, Ky.

M. L. Evans
Designing Engineer, Chief Civil Engineer's Branch, Department of Railways, Sydney, Australia

H. H. Garrigues
Retired Assistant to General Manager, Eastern Region, Pennsylvania Railroad, Radnor, Pa.

Otto Gersbach
Retired Chief Engineer, Indiana Harbor Belt Railroad; Chicago River & Indiana Railroad, Chicago

C. M. Goodrich
Consulting Engineer, Canadian Bridge Company, Walkerville, Ont.

F. W. Grace
Vice-President and General Manager, Missouri–Kansas–Texas Lines, Dallas, Texas

G. T. Hand
Consulting Engineer, Lehigh Valley Railroad, Bethlehem, Pa.

G. A. Haskins
Engineer Maintenance of Way, Akron, Canton & Youngstown Railroad, Akron, Ohio

Deceased Members

J. E. Hogan
Assistant Division Engineer, Chesapeake & Ohio Railway, Hinton, W. Va.

E. A. Johnson
Maine Central Railroad, Portland, Me.

F. G. Jonah
Chief Engineer, St. Louis–San Francisco Railway, St. Louis, Mo.

W. A. Madeley
(In Armed Service)
Resident Engineer, Pacific Great Eastern Railway, Squamish, B. C.

A. F. Maischaider
Retired Principal Assistant Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, Cincinnati, Ohio

P. B. Motley
Retired Engineer of Bridges, Canadian Pacific Railway, Montreal, Que.

J. C. Patterson
Retired Chief Engineer Maintenance of Way, Erie Railroad, Cleveland, Ohio

J. A. Peabody
Retired Engineer of Maintenance, Chicago & North Western Railway, Evanston, Ill.

W. H. Petersen
Retired Chief Engineer, Chicago, Rock Island & Pacific Railway, Dixon, Ill.

W. F. Rech
Engineer Bridges and Buildings, Alton Railroad, Chicago

J. M. Salmon
Bridge Engineer, Louisville & Nashville Railroad, Louisville, Ky.

C. S. Sheldon
Retired Engineer Bridges and Structures, Pere Marquette Railway, Batavia, Ill.

M. S. Sloan
Chairman of Board and President, Missouri–Kansas–Texas Lines, New York, N. Y.

H. E. Smith
District Engineer, Canadian National Railways, Montreal, Que.

A. F. Sommer
Vice-President and General Manager, Quanah, Acme & Pacific Railway, Quanah, Texas

H. M. Stout
Retired Valuation Engineer, Northern Pacific Railway, Minneapolis, Minn.

W. D. Williams
637 South Washington Street, Van Wert, Ohio

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1945

Balance on hand January 1, 1945			$104,419.84
RECEIPTS			
Membership Account			
Entrance Fees	$ 1,580.00		
Dues	17,891.90		
Binding Proceedings	1,312.00		
		$20,783.90	
Sales of Publications			
Proceedings	1,052.44		
Bulletins	2,054.00		
Manuals	3,015.03		
Specifications	368.50		
Track Plans	1,084.68		
		7,574.65	
Advertising			
Publications		1,446.88	
Interest Account			
Interest on Investments	2,469.94		
Less Interest Paid on Bonds Purchased	28.46		
		2,441.48	
Miscellaneous		58.72	
Total		$32,305.63	
DISBURSEMENTS			
Salaries		$10,504.00	
Proceedings		4,101.49	
Bulletins		4,922.26	
Stationery and Printing		918.09	
Rents, Lights, etc.		780.00	
Supplies		129.42	
Postage		712.05	
Refunds, Dues, etc.		35.48	
Audit, Year 1944		250.00	
Pension		1,200.00	
Social Security and Unemployment Taxes		365.44	
Manual		3,908.08	
Track Plans		60.00	
Committee and Officers Expense		105.75	
Annual Meeting Expense		66.30	
News Letter		1,052.55	
Miscellaneous		189.34	
Total		$29,300.25	
Excess of Receipts over Disbursements		3,005.38	
Loss on Sales of Bonds		69.05	
			2,936.33
Balance on hand December 31, 1945			$107,356.17

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1945		$104,419.84
Receipts during 1945	$32,305.63	
Paid out on Audited Vouchers	29,300.25	
Loss on Sale of Bonds	69.05	
Excess of Receipts over Disbursements		2,936.33
Balance on hand December 31, 1945		$107,356.17
Consisting of		
Bonds at cost		91,854.32
Cash in Northern Trust Company Bank		14,289.08
Cash in Royal Bank of Canada		1,187.77
Petty Cash		25.00
		$107,356.17

We have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1945, and find them to be in accordance with the foregoing statements.

CARL BICK,
PAUL MITCHELL,
Auditors.

GENERAL BALANCE SHEET

December 31, 1945

ASSETS	1945	1944
Due from Members	$ 617.50	$ 595.50
Due from Sales of Publications	107.35	19.05
Due from Advertising	145.00	104.00
Furniture and Fixtures	332.92	352.84
Publications on hand (estimated)	729.00	810.00
Investments (cost)	91,854.32	82,520.50
Interest on Investments (accrued)	620.81	612.66
Cash in Northern Trust Company Bank	14,289.08	21,739.81
Cash in Royal Bank of Canada	1,187.77	134.53
Petty Cash	25.00	25.00
Manuals (on hand)	2,536.30	1,939.00
Track Plans	1,124.00	1,613.70
Paper Stock	980.00	508.20
Total	$114,549.05	$110,974.79
LIABILITIES		
Members' Dues Paid in Advance	$ 6,044.00	$ 6,069.00
Surplus	108,505.05	104,905.79
Total	$114,549.05	$110,974.79

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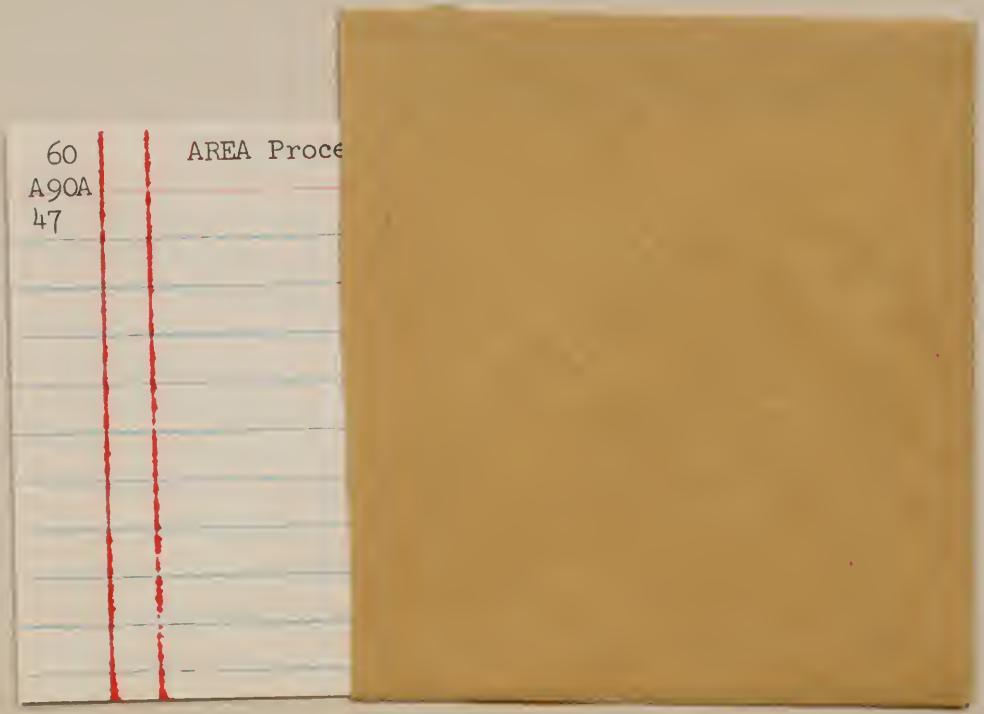
60
A90A
47
AREA Proce